DRAFT Landusky Metals and Cyanide Total Maximum Daily Loads and Framework Water Quality Restoration Plan

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The authors take sole responsibility for the contents of the report and will consider additional review comments for future publication or additional efforts derived from this report. The participation of all contributors led to substantial improvements in our understanding of the available water quality data and water management issues at the mines. Their generous contributions of time and effort are greatly appreciated.

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ACRONYMS

Acronym	Definition
AAL	Acute Aquatic Life
AML	Abandoned Mine Lands
ARARS	Applicable or Relevant and Appropriate Requirements
ARD	Acid Rock Drainage
ARM	Administrative Rules of Montana
BER	Board of Environmental Review (Montana)
BLM	Bureau of Land Management (federal)
BMP	Best Management Practices
CAL	Chronic Aquatic Life
CAMA	Computer Assisted Mass Appraisal
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CN	Cyanide
CWA	Clean Water Act
DEM	Digital Elevation Model
DEQ	Department of Environmental Quality (Montana)
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency (US)
FWP	Fish, Wildlife, and Parks
GIS	Geographic Information System
GPM	Gallons Per Minute
HH	Human Health
IR	Integrated Report
LA	Load Allocation
LAD	Land Application Area
LULC	Land Use and Land Cover
MBMG	Montana Bureau of Mines and Geology
MCA	Montana Codes Annotated
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MMI	Multimetric Indices
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
NAIP	National Agricultural Imagery Program
NHD	National Hydrography Data(set)
NLCD	National Land Cover Dataset
NOAA	National Oceanographic and Atmospheric Administration
NPL	National Priorities List
NRCS	National Resources Conservation Service
NRIS	Natural Resource Information System (Montana)
NWIS	National Water Information System
PEL	Probable Effects Levels
RAWS	Remote Automatic Weather Stations
RIT/RDG	Resource Indemnity Trust/Reclamation and Development Grants Program

Acronym	**Definition**
RIT	Reach Indexing Tool
SDWIS	Safe Drinking Water Information System
SEIS	Supplemental Environmental Impact Statement
SILC	Satellite Imagery Land Cover
SSURGO	Soil Survey Geographic database
STORET	EPA STOrage and RETrieval database
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TPA	TMDL Planning Area
TSS	Total Suspended Solids
UAA	Use Attainability Analysis
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
UTMS	Untreated Mining Sources
WLA	Waste Load Allocation
WQ	Water Quality
WQA	Water Quality Act
WRP	Watershed Restoration Plans
WWTP	Waste Water Treatment Plant
ZMI	Zortman Mining, Inc.

DOCUMENT SUMMARY

This document presents a Total Maximum Daily Load (TMDL) and framework water quality improvement plan for 12 impaired headwater tributaries to the Missouri and Milk rivers located in the Little Rocky mountain range in north-central Montana (**Appendix A, Figure A-7**).

The Montana Department of Environmental Quality (DEQ) develops TMDLs and submits them to the U.S. Environmental Protection Agency (EPA) for approval. The Montana Water Quality Act requires DEQ to develop TMDLs for streams and lakes that do not meet, or are not expected to meet, Montana water quality standards. A TMDL is the maximum amount of a pollutant a waterbody can receive and still meet water quality standards. TMDLs provide an approach to improve water quality so that streams and lakes can support and maintain their state-designated beneficial uses.

The Landusky TMDL Planning Area (TPA) is located in southwestern Phillips County. The tributaries originate in the Little Rocky Mountains. The Landusky TPA encompasses about 81,900 acres, with federal, state, and private land ownership.

DEQ determined that 12 tributaries do not meet the applicable water quality standards. The scope of the TMDLs in this document addresses problems with trace metal sand cyanide (see **Table DS-1**). Although DEQ recognizes that there are fecal coliform and nitrate nitrogen pollutant listings for this TPA, this document addresses only metals and cyanide. A future TMDL project will be developed to address the coliform and nitrogen TMDLs for this planning area.

The chronic and acute toxicity of metal and cyanide pollutants were identified as impairing cold water fishes, warm water fishes, drinking water uses, primary contact recreation, and agricultural and industrial uses in planning area streams. Water quality restoration goals for metals and cyanide are established on the numeric water quality criteria for these pollutants published in Circular DEQ-7 (DEQ 2010). DEQ believes that once these water quality goals are met, all water uses currently affected by metals and cyanide will be restored.

Recommended framework strategies for achieving the pollutant reduction goals are also presented in this plan. They include best management practices (BMPs) such as repair and maintenance of existing wastewater treatment components, continued lime treatment of collected wastewater, conversion form sodium hydroxide to lime treatment for leach pad drainage, and improvements in capture system efficiency.

Implementation of most water quality improvement measures described in this plan is based on required compliance with numeric water quality standards for treatment plant point sources and waste loads allocated to mining sources of metals and cyanide. Local, state, federal and tribal agency stakeholders will, ideally, use this TMDL, and associated information, as a guidance tool for water quality improvements. Such activities will be documented in an updated engineering evaluation and cost analysis document that is consistent with achievable local, state, federal and tribal recommendations.

A flexible approach to control of point source TMDL implementation activities is necessary in the Landusky TPA as water quality managers respond to a combination of extreme climate events, changing acidity conditions within waste streams, and escalating costs for power supplies, labor, equipment and materials. Flexibility is also crucial in formulating new water treatment strategies as more knowledge is gained through on-going treatment operations and future monitoring. The plan includes broad monitoring recommendations to improve knowledge of how treatment options are affecting downstream water quality and to update water quality analyses for a more precise comparison with standards.

Table DS-1. List of impaired waterbodies and their impaired uses in the Landusky TPA with metals and cyanide TMDLs contained in this document

Waterbody & Location Description	TMDLs Prepared	Impaired Uses
ALDER GULCH, headwaters to mouth (Ruby Creek)	Cadmium, Copper, Lead, Mercury, Selenium, Zinc	Aquatic Life Warm Water Fishes Primary Contact Recreation
		Aquatic Life, Cold Water Fishery
BEAVER CREEK, headwaters to Fort Belknap Reservation boundary	Lead	Agriculture Aquatic Life Drinking Water Industrial Primary Contact Recreation Warm Water Fishes
SOUTH BIG HORN CREEK, Zortman Mine to Fort Belknap Reservation boundary	Aluminum, Arsenic, Cadmium, Iron, Nickel, Zinc	Agriculture Aquatic Life Cold Water Fishes Drinking Water Industrial Primary Contact Recreation
KING CREEK, headwaters to Fort Belknap Reservation boundary	Arsenic, Cadmium, Selenium	Agriculture Aquatic Life Cold Water Fishes Drinking Water Industrial Primary Contact Recreation
LODGE POLE CREEK, headwaters to Fort Belknap Reservation boundary	Cadmium, Mercury	Agriculture Aquatic Life Cold Water Fishes Drinking Water Industrial Primary Contact Recreation
MILL GULCH, headwaters to mouth (Rock Creek)	Copper, Mercury, Selenium	Agriculture Aquatic Life Drinking Water Industrial Primary Contact Recreation Warm Water Fishes
MONTANA GULCH, headwaters to mouth (Rock Creek)	Arsenic, Cadmium, Cyanide, Nickel, Selenium, Zinc	Aquatic Life Primary Contact Recreation Warm Water Fishes

Table DS-1. List of impaired waterbodies and their impaired uses in the Landusky TPA with metals and cyanide TMDLs contained in this document

Waterbody & Location Description	TMDLs Prepared	Impaired Uses
ROCK CREEK, headwaters to mouth (Missouri River)	Cadmium, Copper, Lead, Mercury, Selenium, Zinc	Aquatic Life Primary Contact Recreation Warm Water Fishes
RUBY CREEK, un-named tributary T25N R25E S21 to mouth (CK Creek)	Aluminum, Cadmium, Copper, Lead, Mercury, Selenium, Zinc	Aquatic Life Primary Contact Recreation Warm Water Fishes
RUBY GULCH, headwaters to confluence of Alder Gulch	Aluminum, Cadmium, Cyanide, Chromium, Mercury, Selenium	Aquatic Life Primary Contact Recreation Warm Water Fishes
SULLIVAN GULCH, headwaters to mouth (Rock Creek)	Cadmium, Iron, Lead, Selenium, Zinc	Aquatic Life Primary Contact Recreation Warm Water Fishes
SWIFT GULCH CREEK, headwaters to mouth (South Big Horn Creek)	Aluminum, Arsenic, Cadmium, Copper, Cyanide, Iron, Lead, Nickel, Thallium, Zinc	Agriculture Aquatic Life Cold Water Fishes Drinking Water Industrial Primary Contact Recreation

1.0 INTRODUCTION

This document presents an analysis of water quality information and establishes total maximum daily loads (TMDLs) for metals and cyanide problems in the Landusky TPA. This document also presents a general framework for resolving these problems. **Figure A-7**, found in **Appendix A**, shows a map of waterbodies in the Landusky TPA with metals and cyanide pollutant listings.

1.1 BACKGROUND

In 1972, the U.S. Congress passed the Water Pollution Control Act, more commonly known as the Clean Water Act (CWA). The CWA's goal is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The CWA requires each state to designate uses of their waters and to develop water quality standards to protect those uses. Each state must monitor their waters to track if they are supporting their designated uses.

Montana's water quality designated use classification system includes the following uses:

- fish and aquatic life
- wildlife
- recreation
- agriculture
- industry
- drinking water

Each waterbody has a set of designated uses. Montana has established water quality standards to protect these uses. Waterbodies that do not meet one or more standards are called impaired waters. Every two years DEQ must file a Water Quality Integrated Report (IR), which lists all impaired waterbodies and their identified impairment causes. Impairment causes fall within two main categories: pollutant and non-pollutant.

Montana's biennial IR identifies all the state's impaired waterbody segments. All waterbody segments within the IR are indexed to the National Hydrography Dataset (NHD). The 303(d) list portion of the IR includes all of those waterbody segments impaired by a pollutant, which require a TMDL. TMDLs are not required for non-pollutant impairments. **Table A-1** in **Appendix A** identifies impaired waters for the Landuksy TPA from Montana's 2010 303(d) List, as well as non-pollutant impairment causes included in Montana's "2010 Water Quality Integrated Report." **Table A-1** also provides the current status of each impairment cause, identifying whether it has been addressed by TMDL development.

Both Montana state law (Section 75-5-701 of the Montana Water Quality Act) and section 303(d) of the federal CWA require the development of total maximum daily loads for all impaired waterbodies when water quality is impaired by a pollutant. A TMDL is the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards.

Developing TMDLs and water quality improvement strategies includes the following components, which are further defined in **Section 4.0**:

- Determining measurable target values to help evaluate the waterbody's condition in relation to the applicable water quality standards

- Quantifying the magnitude of pollutant contribution from their sources
- Determining the TMDL for each pollutant based on the allowable loading limits for each waterbody-pollutant combination
- Allocating the total allowable load (TMDL) into individual loads for each source

In Montana, restoration strategies and monitoring recommendations are also incorporated in TMDL documents to help facilitate TMDL implementation.

Basically, developing a TMDL for an impaired waterbody is a problem-solving exercise: The problem is excess pollutant loading that impairs a designated use. The solution is developed by identifying the total acceptable pollutant load (the TMDL), identifying all the significant pollutant-contributing sources, and identifying where pollutant loading reductions should be applied to achieve the acceptable load.

1.2 Water Quality Impairments and TMDLs Addressed by this Document

Table 1-1 below lists all of the impairment causes from the "2010 Water Quality Integrated Report" that are addressed in this document. All pollutant impairments fall within the metals TMDL pollutant category.

Data assessed during this project identified new impairment causes for five waterbodies. These impairment causes are identified in **Table 1-1** as not being on the 2010 303(d) List (within the integrated report).

TMDLs are completed for each waterbody – pollutant combination, and this document contains 68 TMDLs (**Table 1-1**). Non-pollutant impairment causes are not addressed in this document. As noted above, TMDLs are not required for non-pollutants, although in some situations the solution to one or more pollutant problems may be consistent with the solution for one or more non-pollutant problems. Listings of pH impairment causes in this document are addressed by surrogate TMDLs developed for metals causes. Solutions to low pH conditions are also effective in addressing metals impairments. **Section 7.0** provides some basic water quality solutions to addressing metals impairments that also serve to address pH impairments.

Although DEQ recognizes that there are pollutant listings for the Landusky TPA without completed TMDLs (**Table A-1** in **Appendix A**), this document only addresses those identified in **Table 1-1**. This is because DEQ sometimes develops TMDLs in a watershed at varying phases, with a focus on one or a couple of specific pollutant types. **Table A-1** in **Appendix A** includes impairment causes with completed TMDLs, as well as non-pollutant impairment causes that need to be address by future planning efforts.

Table 1-1. Water quality impairment causes for the Landusky TPA addressed within this document

Waterbody & Location Description	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status	Included in 2010 Integrated Report*
ALDER GULCH, headwaters to mouth (Ruby Creek)	MT40E002_050	Cadmium	Metals	Cadmium TMDL completed	Yes
		Copper	Metals	Cooper TMDL completed	Yes
		Lead	Metals	Lead TMDL completed	No
		Mercury	Metals	Mercury TMDL completed	Yes
		Selenium	Metals	Selenium TMDL completed	Yes
		Zinc	Metals	Zinc TMDL completed	Yes
		pH	pH/Acidity/Caustic Conditions	Addressed by Cd TMDL	Yes
BEAVER CREEK, headwaters to Fort Belknap Reservation boundary	MT40M001_011	Lead	Metals	Lead TMDL completed	Yes
SOUTH BIG HORN CREEK, Zortman Mine to Fort Belknap Reservation boundary	MT40I001_030	Aluminum	Metals	Aluminum TMDL completed	Yes
		Arsenic	Metals	Arsenic TMDL completed	Yes
		Cadmium	Metals	Cadmium TMDL completed	Yes
		Iron	Metals	Iron TMDL completed	No
		Nickel	Metals	Nickel TMDL completed	Yes
		Zinc	Metals	Zinc TMDL completed	Yes
KING CREEK, headwaters to Fort Belknap Reservation boundary	MT40I001_040	Arsenic	Metals	Arsenic TMDL completed	No
		Cadmium	Metals	Cadmium TMDL completed	No
		Selenium	Metals	Selenium, TMDL completed	Yes
LODGE POLE CREEK, headwaters to Fort Belknap Reservation boundary	MT40I001_050	Cadmium	Metals	Cadmium TMDL completed	Yes
		Mercury	Metals	Cadmium TMDL completed	Yes
MILL GULCH, headwaters to mouth (Rock Creek)	MT40E002_100	Copper	Metals	Copper TMDL completed	Yes
		Mercury	Metals	Mercury TMDL completed	Yes
		Selenium	Metals	Selenium TMDL completed	Yes
		pH	pH/Acidity/Caustic Conditions	Addressed by Cu TMDL	Yes
MONTANA GULCH, headwaters to mouth (Rock Creek)	MT40E002_010	Arsenic	Metals	Arsenic TMDL completed	Yes
		Cadmium	Metals	Cadmium TMDL completed	Yes
		Cyanide	Toxin	Cyanide TMDL completed	No
		Nickel	Metals	Nickel TMDL completed	No
		Selenium	Metals	Selenium TMDL completed	No
		Zinc	Metals	Zinc TMDL completed	No
		pH	pH/Acidity/Caustic Conditions	Addressed by Cd TMDL	Yes

Table 1-1. Water quality impairment causes for the Landusky TPA addressed within this document

Waterbody & Location Description	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status	Included in 2010 Integrated Report*
ROCK CREEK, headwaters to mouth (Missouri River)	MT40E002_090	Cadmium	Metals	Cadmium TMDL completed	Yes
		Copper	Metals	Copper TMDL completed	Yes
		Mercury	Metals	Mercury TMDL completed	Yes
		Lead	Metals	Lead TMDL completed	Yes
		Selenium	Metals	Selenium TMDL completed	Yes
		Zinc	Metals	Zinc TMDL completed	Yes
		pH	pH/Acidity/Caustic Conditions	Addressed by Cd TMDL	Yes
RUBY CREEK, un-named tributary T25N R25E S21 to mouth (CK Creek)	MT40E002_060	Aluminum	Metals	Aluminum TMDL completed	Yes
		Cadmium	Metals	Cadmium TMDL completed	Yes
		Copper	Metals	Cooper TMDL completed	Yes
		Mercury	Metals	Mercury TMDL completed	Yes
		Lead	Metals	Lead TMDL completed	Yes
		Selenium	Metals	Selenium TMDL completed	Yes
		Zinc	Metals	Zinc TMDL completed	Yes
		pH	pH/Acidity/Caustic Conditions	Addressed by Cd TMDL	Yes
RUBY GULCH, headwaters to confluence of Alder Gulch	MT40E002_070	Aluminum	Metals	Aluminum TMDL completed	No
		Cadmium	Metals	Cadmium TMDL completed	Yes
		Cyanide	Toxin	Cyanide TMDL completed	No
		Chromium	Metals	Chromium TMDL completed	Yes
		Mercury	Metal	Mercury TMDL complete	Yes
		Selenium	Metals	Selenium TMDL completed	Yes
		pH	pH/Acidity/Caustic Conditions	Addressed by Cd TMDL	Yes
SULLIVAN GULCH, headwaters to mouth (Rock Creek)	MT40E002_110	Cadmium	Metals	Cadmium TMDL completed	No
		Lead	Metals	Lead TMDL completed	No
		Iron	Metals	Iron TMDL completed	No
		Selenium	Metals	Selenium TMDL completed	No
		Zinc	Metals	Zinc TMDL completed	No

Table 1-1. Water quality impairment causes for the Landusky TPA addressed within this document

Waterbody & Location Description	Waterbody ID	Impairment Cause	Pollutant Category	Impairment Cause Status	Included in 2010 Integrated Report*
SWIFT GULCH CREEK, headwaters to mouth (South Big Horn Creek)	MT40I002_010	Aluminum	Metals	Aluminum TMDL completed	Yes
		Arsenic	Metals	Arsenic TMDL completed	Yes
		Cadmium	Metals	Cadmium TMDL completed	Yes
		Cadmium	Metals	Cadmium TMDL completed	Yes
		Cyanide	Toxin	Cyanide TMDL completed	Yes
		Iron	Metals	Iron TMDL completed	Yes
		Lead	Metals	Lead TMDL completed	Yes
		Nickel	Metals	Nickel TMDL completed	Yes
		Thallium	Metals	Zinc TMDL completed	Yes
		Zinc	Metals	Zinc TMDL completed	Yes

*Impairment causes not in the "2010 Water Quality Integrated Report" were recently identified and will be included in the 2012 Integrated Report.

1.3 Document Layout

This document addresses all of the required components of a TMDL and includes a framework implementation and monitoring strategy. The TMDL components are summarized within the main body of the document. Additional technical details are contained in the appendices. In addition to this introductory section, this document includes:

Section 2.0 Landusky TMDL planning area description:
Describes the physical characteristics and social profile of the watershed.

Section 3.0 Montana Water Quality Standards
Discusses the water quality standards that apply to the Landusky TPA.

Section 4.0 Defining TMDLs and Their Components
Defines the components of TMDLs and how each is developed.

Sections 5.0 Metals TMDL Components
Each section includes (a) a discussion of the affected waterbodies and the pollutant's effect on designated beneficial uses, (b) the information sources and assessment methods used to evaluate stream health and pollutant source contributions, (c) water quality targets and existing water quality conditions, (d) the quantified pollutant loading from the identified sources, (e) the determined TMDL for each waterbody, (f) the allocations of the allowable pollutant load to the identified sources.

Section 6.0 Framework Water Quality Restoration Strategy:
Discusses water quality restoration objectives and presents a framework for implementing a strategy to meet the identified objectives and TMDLs.

Section 7.0 Monitoring Strategy and Adaptive Management:
Describes a water quality monitoring plan for evaluating the long-term effectiveness of the Landusky Metals and Cyanide TMDLs and Framework Water Quality Restoration Plan.

2.0 INTRODUCTION

This report describes the physical, ecological, and cultural characteristics of the Rock Creek watershed and nearby areas in the uplands of the Little Rocky Mountains. The characterization establishes a context for impaired waters to support total maximum daily load (TMDL) planning. The area described is known as the Landusky TMDL Planning Area (TPA).

The Montana Department of Environmental Quality (DEQ) has identified 12 impaired (Category 5 and 4C) waterbodies within the Landusky TPA: Alder Gulch, Beaver Creek, South Big Horn Creek, King Creek, Lodgepole Creek, Mill Gulch, Montana Gulch, Rock Creek, Ruby Creek, Ruby Gulch, Swift Gulch Creek, and Sullivan Gulch. Sullivan Gulch is classified Category 4C; the other streams are Category 5. The impairments are detailed in DEQ's Integrated 305(b)/303(d) Water Quality Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010), and are not discussed in this report. For the reader's convenience, listings extracted from the report are listed in **Table 3-1**. A total of 69.8 miles of streams in the TPA are listed as impaired. The map figures referenced in the following discussion are contained in **Appendix A**.

2.1 PHYSICAL PARAMETERS

2.1.1 Location

The Landusky TPA is within Phillips County. The total extent is 81,900 acres, or approximately 128 square miles. The TPA is located in the Middle Missouri Basin (Accounting Unit 100401) of central Montana, and within the Fort Peck Reservoir fourth-code watershed, as shown in **Appendix A, Figure 2-1**. The TPA is coincident with the 1004010406 fifth-code watershed (Rock Creek), enlarged northward to include areas of the Little Rocky Mountains not located within the Fort Belknap Indian Reservation.
The TPA spans three Level III Ecoregions: Middle Rockies (17), Northwestern Glaciated Plains (42), and Northwestern Great Plains (43). Four Level IV Ecoregions are mapped within the TPA (Woods, et al., 2002), as shown on **Appendix A, Figure 2-2**. These include: Foothill Grassland (42r), Glaciated Northern Grassland (42j), Missouri Breaks Woodland-Scrubland (43l), and Scattered Eastern Igneous-Core Mountains (17r).

The TPA is bounded by the drainage divides to the east, west, and south, and the boundary of the Fort Belknap Reservation to the north.

2.1.2 Topography

Elevations in the Landusky TPA range from approximately 686 to 1,748 meters (2,250 – 5,733 feet) above mean sea level (**Appendix A, Figure 2-3**). The lowest point is the confluence of Rock Creek and the Missouri River. The highest point is Antoine Butte, in the heart of the Little Rocky Mountains. The landscape is characterized by mountains, plains and badlands.

2.1.3 Geology

Appendix A, Figure 2-4 provides an overview of the geology, based on a geologic map of the Zortman quadrangle (Porter and Wilde, 2001).

2.1.3.1 Bedrock
The bedrock of the TPA includes Precambrian (pre-Belt Series) metamorphic rocks, Paleozoic and Mesozoic sedimentary rocks, and Tertiary igneous rocks. Tertiary igneous rocks form the core of the Little Rocky Mountains, and their emplacement caused the surrounding rocks to deform into a dome around and over the intrusion. Later erosion stripped much of this rock away from the igneous rocks, leaving the older rocks exposed on the margins of the Little Rocky Mountains. The plains are dominated by Mesozoic sedimentary rocks, of which the Cretaceous section is the most aerially extensive. These rocks underlie wide expanses of the northern plains, including much of the Landusky TPA.

2.1.3.2 Recent Sediments
Older Tertiary and Quaternary alluvial sediments are present on dissected pediments surrounding the Little Rocky Mountains. More recent alluvial deposits are located within modern stream channels that are incised into the Cretaceous sedimentary rocks.

2.1.3.3 Soils
The USGS Water Resources Division (Schwarz and Alexander, 1995) created a dataset of hydrology-relevant soil attributes, based on the USDA Natural Resources Conservation Service (NRCS) STATSGO soil database. The STATSGO data are intended for small-scale (watershed or larger) mapping, and is too general to be used at scales larger than 1:250,000. It is important to realize, therefore, that each soil unit in the STATSGO data may include up to 21 soil components. Soil analysis at a larger scale should use NRCS SSURGO data. The soil attributes considered in this characterization are erodibility and slope.
Soil erodibility is based on the Universal Soil Loss Equation (USLE) K-factor (Wischmeier and Smith, 1978). K-factor values range from 0 to 1, with a greater value corresponding to greater potential for erosion. Susceptibility to erosion is mapped on **Appendix A, Figure 2-5**, with soil units assigned to the following ranges: low (0.0-0.2), moderate-low (0.2-0.29) and moderate-high (0.3-0.4). Values of >0.4 are considered highly susceptible to erosion. No values greater than 0.39 are mapped in the TPA.
The majority of the TPA (70%) is mapped with moderate-low susceptibility soils. Nearly a third of the TPA is mapped with moderate-high susceptibility (29%) soils. Low susceptibility soils are mapped in less than 1% of the TPA. The entire area of the Little Rocky Mountains is mapped with moderate-low susceptibility soils.

Appendix A, Figure 2-6, which shows slope interpreted from a 30-meter digital elevation model (DEM), illustrates that the TPA is characterized by three landscapes: mountains, plains and badlands. The mountains and to a lesser extent, the badlands, have locally steep slopes.

2.2 SURFACE WATER

The TPA includes the 5th code watershed 1004010406, and extends northward to the Fort Belknap Indian Reservation. The TPA therefore includes the headwaters of streams that radiate outward from the center of the Little Rocky Mountains into other watersheds (including the Milk River 4th code watershed to the north). Hydrography of the Landusky TPA is illustrated on **Appendix A, Figure 2-7**. The National Hydrography Dataset (NHD) medium resolution data (U.S. Geological Survey, 1999) includes 123 miles of streams mapped in the TPA. This data is compiled at 1:100,000.

2.2.1 Stream Gaging Stations
The United States Geological Survey (USGS) formerly maintained one gaging station within the TPA, as detailed below in **Table 2-1**. The gaging station location is shown in **Appendix A**, **Figure 2-7**.

Table 2-1. Stream Gage

Name	**Number**	**Drainage Area**	**Agency**	**Period of Record**
Rock Creek near Landusky, MT	06115350	72.9 miles^2	USGS	11/1999-9/2004

2.2.2 Stream Flow

Stream flow data are based on records from the USGS stream gage on Rock Creek near Landusky described above, and are available via the Internet from the USGS NWIS site (United States Department of the Interior, 2008). Flows in Rock Creek vary considerably over a calendar year. A hydrograph summarizing mean daily discharge at this station is shown below in **Figure 2.1**

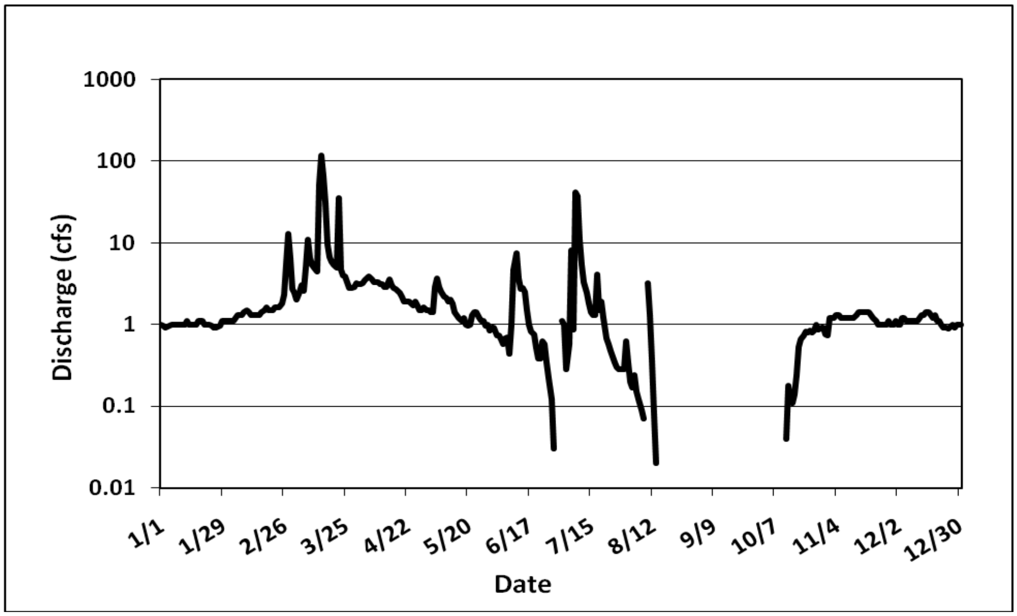

Figure 2-1. Mean daily discharge of Rock Creek at USGS Station 06115350 near Landusky, Montana

Flow is variable from year to year, but on average (over a 5-year period of record), peak flows occur in late winter (February-March) or in July. The highest recorded flow is 567 cubic feet per second (cfs) in March 2003, and probably represents a rain-on-snow event. Annual peaks have ranged from 567 cfs to 12 cfs (March 9, 2001).

Over the period of record, mean high flow occurs in March (13 cfs), and mean low flow occurs in September (0 cfs). Daily discharge data demonstrate that Rock Creek is commonly dry in late summer.

2.2.3 Surface Water Quality

Approximately 290 surface water monitoring stations occur within the TPA boundaries. About 105 of these are listed in the STORET water quality database maintained by the United States Environmental Protection Agency (EPA). The most inclusive water quality database for the planning area is that created and maintained by Spectrum Engineering, Inc. (2005). The database contains water quality analytical results and field measurements for surface and groundwater. It includes pre-mine baseline data, compliance monitoring during active mining by Zortman Mining, Inc. (ZMI), and post-mine reclamation monitoring by Spectrum field staff. **Appendix B** contains a subset of the entire Z-L ACCESS database used to describe exist surface water quality of listed streams. **Appendix C** contains water quality records for sites selected as representing natural background for surface waters.

Surface waters exhibit a wide range in chemical characteristics depending upon the degree of influence from mining sources and distance from the core of the Little Rockies range. Waters remote from mining disturbances are typically low in trace metal and dissolved solids and have a neutral pH. Waters affected by mining are high in dissolved solids, particularly sulfate, have elevate metals concentrations, and have pH values ranging from 3.0 to 9.0. Dissolved solids and pH increase as streams flow from the Little Rocky Mountain uplands onto the surrounding sedimentary plains.

2.3 GROUNDWATER

2.3.1 Hydrogeology

No comprehensive hydrogeology study is available for the entire TPA. Osborne and Gallagher (2001) described the groundwater system within the Zortman and Landusky mine areas as part of the Final Supplemental Environmental Impact Statement (SEIS) prepared by the Bureau of Land Management (BLM) and DEQ (2001). The study described the groundwater flow paths as affected by geologic and mine features, described water balance and chemical mass loading processes, and presented a water quality classification system based on the degree of mine influence on groundwater quality.
A groundwater flow divide occurs at the crest of the Little Rocky Mountains. Groundwater flow within the shallowest aquifer generally mimics surface water flows that radiate outward from the mountain core to the surrounding plains. Surface and groundwater flows south toward the Missouri River and north toward the Milk River from the highest elevations.

Natural groundwater recharge occurs from infiltration of precipitation and loss from stream channels. The extensive open pits, disturbed areas, and underground mine workings at both mine sites has likely increased the rate of groundwater recharge compared to pre-mine conditions (Osborne and Gallagher, 2001). Groundwater affected by bedrock mineralization and mining disturbance has acidic pH and elevated dissolved solids, including metals, compared to groundwaters outside of mineralized zones or mine disturbances.

2.3.2 Groundwater Quality

The Spectrum ACCESS database contains groundwater quality data from over 150 locations that include either wells or springs. Water quality data are available in **Appendix D** for 43 of these sites. The site locations are shown in **Appendix A**, **Figure 2-8**.

The water quality data include general physical parameters: temperature, pH and specific conductance, in addition to inorganic chemistry (common ions, metals and trace elements). Most of the mined rock contains sufficient sulfide minerals to produce acidity when exposed to oxygen and water. Therefore, elevated metals concentrations are common in groundwater. The use of blasting agents and cyanide for ore processing and fertilizers for reclamation have increased groundwater levels of nitrogen. Elevated selenium has resulted from accelerated rock weathering with mining and high selenium concentrations in clay materials used for leach pad liners.

The TPA has one public water supply well operated by the Zortman Water Users Association. This well is completed in the Paleozoic Madison Limestone aquifer. Pump test data from within the planning area indicate little connection between the shallow igneous bedrock aquifer and the deeper Paleozoic aquifer

(Osborne and Gallagher, 2001). Water quality data is available for the Zortman well via the SDWIS State database (Montana Department of Environmental Quality, 2008), although these data reflect the finished water provided to the public, not raw water at the source.

2.4 Climate

Climate in the area is typical of mountains and plains in north-central Montana. Precipitation is most abundant in May and June. Annual average precipitation ranges from 13-21 inches. The mountains receive most of the moisture, and the amount received decreases with elevation, with the least falling at the confluence with the Missouri River. The precipitation data (**Appendix A**, **Figure 2-9**) is mapped by Oregon State University's PRISM Group, using records from NOAA stations (Prism Group, 2004).

See **Table 2-2** below for a climate summary; **Appendix A**, **Figure 2-9** shows the distribution of average annual precipitation.

2.4.1 Climate Stations

National Oceanographic and Atmospheric Administration's (NOAA) National Weather Service operates one weather station in the TPA (Zortman). There are no USDA Natural Resources Conservation Service (NRCS) SNOTEL snowpack monitoring stations within the TPA.

Three additional climate monitoring station are present: BLM remote automatic weather stations (RAWS). RAWS stations are primarily used to assess conditions related to fire hazard, and provide telemetry to the National Interagency Fire Center in Boise, Idaho. The RAWS stations in the TPA include: Zortman Mine (ALDM8); Lewistown Port #2 (TS705); and Manning Corral Dogtown (MCDM8).
Climate data in **Table 2-2** are provided by the MesoWest program, operated by the University of Utah Meteorology Department, and by the Western Regional Climate Center, operated by the Desert Research Institute at the University of Nevada-Reno.

Table 2-2. Monthly Climate Summary: Zortman

Zortman, Montana (249900) Period of Record : 9/1/1965 to 12/31/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave. Max. Temp (F)	31.8	35.2	42.0	52.6	63.0	71.1	79.4	79.4	68.3	55.8	42.2	33.8	54.5
Ave. Min. Temp. (F)	9.7	12.5	19.7	29.0	37.7	45.8	50.8	50.2	40.7	30.7	20.3	12.3	29.9
Ave Tot. Precip. (in.)	0.87	0.53	0.91	1.61	2.96	3.91	2.13	1.78	1.59	0.88	0.48	0.77	18.42
Ave.. Snowfall (in.)	4.7	5.3	6.3	1.3	0.6	0.0	0.0	0.0	0.0	0.3	3.2	5.3	27.0
Ave Snow Depth (in.)	4	4	2	0	0	0	0	0	0	0	1	2	1

2.5 Ecological Parameters

2.5.1 Vegetation

The majority of the land cover in the TPA (55%) is grassland/herbaceous. This area corresponds generally to the plains. The Little Rocky Mountains are mostly covered in evergreen forest (28.5%of of the total area). Shrubland occupies 10.2% of the total, and deciduous forest 2.3%. Open mines account for 1.9% of the total area. Conifers are dominated by Lodgepole pine, giving way to Ponderosa pine at lower elevations, with lesser amounts of Douglas fir, White pine, and juniper. Landcover is shown in **Appendix A**, **Figure 2-10**. Data sources include the University of Montana's Satellite Imagery Land Cover

(SILC) project (University of Montana, 2002), and USGS National Land Cover Dataset (NLCD) mapping (Montana State Library, 1992).

2.5.2 Aquatic Life

Fish are reported in only four streams in the TPA: Beaver Creek, Lodgepole Creek, Montana Gulch and Rock Creek. Fish in Rock Creek are limited to a one-mile section of the lower reach. Native fish species present in the TPA include: bigmouth buffalo, brassy minnow, brook stickleback, emerald shiner, fathead minnow, flathead chub, goldeye, Iowa darter, lake chub, longnose dace, mountain sucker, northern redbelly dace, river carpsucker, shorthead redhorse, smallmouth buffalo, western silvery/plains minnow, and white sucker.

Introduced species are also present, including: black bullhead, bluegill, brook trout, common carp, northern pike, pumpkinseed, smallmouth bass, walleye and yellow perch. Data on fish species distribution are collected, maintained and provided by FWP (2011). Fish species distribution data is shown simply in **Appendix A**, **Figure 2-11** and tabulated in detail in **Appendix E**.

2.5.3 Fires

Fire has played significant economic and ecological roles in the mountainous portion of the planning area. There was a lull in mining activity when the Ruby Gulch Mill burned down in 1913. Fires swept through the mining town of Zortman in 1929 and again in 1944. A substantial area of the Little Rocky Mountains was burned in a 1936 forest fire. Smaller fires burned additional forest lands in 1984 and 1988.

2.6 Cultural Parameters

2.6.1 Population

An estimated 98 persons lived within the TPA in 2000 (Montana Department of Natural Resources and Conservation, 2008). Population estimates are derived from census data (United States Census Bureau, 2000), based upon the populations reported from census blocks within and intersecting the TPA boundary. Populations from Landusky and Zortman are not reported in the 2000 census, either as towns or census designated places (CDPs). Much of the TPA is unpopulated. Census data are mapped in **Appendix A**, **Figure 2-12**.

2.7 Transportation Networks

2.7.1 Roads

The TPA is bisected by US Route 191. The TPA contains a network of unpaved roads on public and private lands.

2.7.2 Railroads

No active or historic railways are present in the TPA.

2.8 Land Ownership

Land ownership data (**Table 2-3**) are provided by the State of Montana CAMA database via the NRIS website (Montana Department of Natural Resources and Conservation, 2008). Slightly more than one-half of the TPA is administered by the US Bureau of Land Management, and 15% by the US Fish &

Wildlife Service. Private lands comprise 23% of the TPA. Montana State Trust Lands occupy 4.5% of the TPA. Land ownership is shown in **Appendix A**, **Figure 2-13**.

Table 2-3. Land Ownership

Owner	Acres	Square Miles	% of Total
US Bureau of Land Management	45,931	71.77	56%
Private	19,240	30.06	23%
US Fish & Wildlife Service	12,584	19.66	15%
Montana State Trust Land	3,701	5.78	4%
Bureau of Indian Affairs Trust Land	373	0.58	0.5%
Total	81,911*	127.99	—

*includes 83 acres of water

2.9 Land Use & Cover

Land use within the TPA (**Table 2-4**) is dominated by forest and agriculture. Agricultural use in the lowlands is primarily livestock grazing. Information on land use is based on land use and land cover (LULC) mapping completed by the USGS in the 1980s. The data are at 1:250,000 scale, and are based upon manual interpretation of aerial photographs. Agricultural land use is illustrated in **Appendix A**, **Figure 2-14**. Potential sources of human impacts (abandoned mines, timber harvest, livestock feeding areas) are illustrated in **Appendix A**, **Figure 2-15**.

Table 2-4. Land Use and Cover

Land Use	Acres	Square Miles	% of Total
Grasslands/Herbaceous	44,819.6	70.0	54.73%
Evergreen Forest	23,323.1	36.4	28.48%
Shrubland	8,337.5	13.0	10.18%
Deciduous Forest	1,855.7	2.9	2.27%
Quarries/Strip Mines/Gravel Pits	1,578.3	2.5	1.93%
Bare Rock/Sand/Clay	1,064.3	1.7	1.30%
Small Grains	264.7	0.4	0.32%
Open Water	165.8	0.3	0.20%
Mixed Forest	147.5	0.2	0.18%
Pasture/Hay	125.1	0.2	0.15%
Commercial/Industrial/Transportation	103.3	0.2	0.13%
Fallow	101.7	0.2	0.12%
Row Crops	4.8	0.0	0.01%
Woody Wetlands	4.0	0.0	0.00%
Emergent Herbaceous Wetlands	3.3	0.0	0.00%

Additional information on agricultural land use can be obtained from Department of Revenue data. The Department of Revenue assigns a predominant agricultural use only if more than 50% of a given parcel is so used, and then the entire acreage is ascribed to that use. A total of 144 acres of irrigated land is reported in the TPA. The dominant designated agricultural use is grazing, corresponding to 17,685 acres (28 square miles) or 22% of the TPA area (Montana Department of Natural Resources and Conservation, 2008).

2.9.1 Mining

Until recently, mining was a major portion of the economy in the TPA. Waste rock and tailings are still present in many locations. Production began later than many other Montana districts. Gold-bearing placers were first widely discovered in 1884. Lode deposits were first worked in 1890.

2.9.1.1 Historic Mining Activity

Like many mining districts, The Little Rockies district experienced several periods of intense activity separated by relative lulls. Lode mines were especially active in the early 1890s, 1903-1912, and during the 1930s.

DEQ Remediation Division data on abandoned mine locations are plotted in **Appendix A**, **Figure 2-15**. Modern Activity

Two large open pit gold mines operated from 1979 to 1998. The Zortman mine permit included 406 acres (**Figure A-16**), and the Landusky permit included 783 acres (**Figure A-17**) (Mitchell, 2004). Exposure of sulfide ores and associated tailings caused acid rock drainage (ARD) issues, and several leaks from the cyanide leach pits were documented.

2.9.2 Timber Harvests

No maps of timber harvests were identified. The ‘transitional’ classification in NLCD is commonly applied to harvested or burned areas, and this classification is not mapped in the TPA.

2.9.3 Livestock Operations

The Montana Pollution Discharge Elimination System (MPDES) does not report any regulated concentrated animal feeding operations (CAFOs) within the TPA.

2.10 WASTEWATER

There are no MPDES regulated discharges within the TPA. Reclamation of mine features and operation of four wastewater treatment facilities have been occurring under authority of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) since June of 2004. Wastewater treatment of ARD affected water is occurring at plants located at the Landusky Mine, Zortman Mine and in the Swift Gulch Creek drainage using pH adjustment with hydrated lime.

A separate biological plant operates at the Landusky Mine for removal of nitrogen from leach pad seepage. The plant at Zortman treats an annual average of about 70 million gallons of wastewater collected from three drainage capture systems. The Landusky plant treats an annual average of about 225 million gallons from drainage capture systems, the biological treatment plant, groundwater piped from a nearby mine adit, and leach pad drains. The Swift Gulch Creek plant began operation in June of 2010. It treats wastewater from two drainage capture systems in Swift Gulch Creek. The plant capacity is approximately 800 gallons per minute. Neither Zortman nor Landusky is sewered. Domestic wastewater treatment is provided by on-site septic tanks and drainfields.

Septic system density is estimated from the 2000 census block data, based on the assumption of one septic tank and drainfield for each 2.5 persons (Montana Department of Natural Resources and Conservation, 2008), and that sewer systems correspond to incorporated communities. Septic system density is classified as low (<50 per square mile), moderate (51-300 per square mile) or high (>300 per square mile). Nearly all of the TPA is mapped as low septic system density, with very limited areas of moderate (35 acres) density. The moderate density locations are found in Zortman. Septic system density is illustrated in **Appendix A**, **Figure 2-15**.

3.0 TMDL Regulatory Framework

3.1 TMDL Development Requirements

Section 303(d) of the Federal Clean Water Act (CWA) requires states to identify waterbodies within its boundaries that do not meet water quality standards. States track these impaired or threatened waterbodies with a 303(d) List. Recently the name for the 303(d) List has changed to Category 5 of Montana's Water Quality Integrated Report. State law identifies that a consistent methodology is used for determining the impairment status of each waterbody. The impairment status determination methodology is identified in The Montana Department of Environmental Quality Metals Assessment Method (Montana Department of Environmental Quality,2011).

Under Montana State Law, an "impaired waterbody" is defined as a waterbody or stream segment for which sufficient credible data show that the waterbody or stream segment is failing to achieve compliance with applicable water quality standards (Montana Water Quality Act; Section 75-5-103(11)). A "threatened waterbody" is defined as a waterbody or stream segment for which sufficient credible data and calculated increases in loads show that the waterbody or stream segment is fully supporting its designated uses but threatened for a particular designated use because of: (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices; or (b) documented adverse pollution trends (Montana Water Quality Act; Section 75-5-103(31)). State Law and section 303 of the CWA require states to develop TMDLs for impaired or threatened waterbodies.

A TMDL is a pollutant budget for a waterbody identifying the maximum amount of the pollutant that a waterbody can assimilate without causing applicable water quality standards to be exceeded. TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in units of mass per time such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources in addition to natural background sources, and need to incorporate a margin of safety and consider seasonality. In Montana, TMDL development is often accomplished in the context of an overall water quality plan. The water quality plan includes not only the actual TMDL, but also includes information that can be used to effectively restore beneficial water uses that have only been affected by pollution, such as habitat degradation or flow modification that are not covered by the TMDL program.

To satisfy the Federal Clean Water Act and Montana State Law, TMDLs are developed for each waterbody-pollutant combination identified on the states list of impaired or threatened waters and are often presented within the context of a water quality restoration or protection plan. State Law (Administrative Rules of Montana 75-5-703(8)) also directs DEQ to "support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for waterbodies that are subject to a TMDL ……" This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing Federal, State, or Local regulations. Montana TMDL laws provide a 5-year review process to allow for an adaptive management approach to update the TMDL and water quality restoration plan.

3.2 Waterbodies and Pollutants of Concern

A recent court ruling and subsequent settlements have obligated the U.S. EPA and the State of Montana to use pollutant/waterbody combinations from the Montana's 1996 List of impaired waters. State and federal guidance indicates that the most recent list be used for determining the need for TMDLs. Metals, pH, and cyanide pollutants that have appeared on the 2010 list are addressed in the impairment status review, TMDLs, or watershed restoration plans presented in this document. Most pollutants identified on the 2010 list are addressed; however several are not addressed at this time due to logistical and budget constraints. These listings will be identified in a follow up monitoring strategy and addressed within a timeframe identified in Montana's law (*Montana Code Annotated 75-5-703*). However, TMDLs were not prepared for impairments where additional information suggests that the initial listings were inaccurate, or where conditions had improved sufficiently since the listing to an extent that the pollutant no longer impairs a beneficial use. Where a pollutant is recommended for removal from the list, justification is provided in the sections that follow. **Table 3-1** provides a summary of waterbody listings and their beneficial use support status for the 2010 303(d) List for the Landusky Fork TPA. Specific probable causes of impairment for each of the impaired waterbodies is found in **Table 1-1**, in **Section 1**.

Table 3-1. Landusky impaired waterbody segments and beneficial use support status

Waterbody & Stream Description	Waterbody #	Use Class	Aquatic Life	Fisheries - Cold	Fisheries - Warm	Drinking Water	Primary Contact (Recreation)	Agriculture	Industry
Alder Gulch, headwaters to mouth (Ruby Creek)	MT40E002_050	C-3	N	NA	N	NA	X	NA	NA
Beaver Creek, headwaters to Fort Belknap Reservation Boundary	MT40M001_011	B-3	N	NA	N	F	F	F	F
South Big Horn Creek, Zortman Mine to Fort Belknap Reservation Boundary	MT40I001_030	B-1	N	N	NA	N	X	F	F
King Creek, headwaters to Fort Belknap Reservation Boundary	MT40I001_040	B-1	N	N	NA	F	X	F	F
Lodge Pole Creek, headwaters to Fort Belknap Reservation Boundary	MT40I001_050	B-1	N	N	NA	N	X	F	F
Mill Gulch, headwaters to mouth (Rock Creek)	MT40E002_100	B-1	P	NA	P	P	X	P	P
Montana Gulch, headwaters to mouth (Rock Creek)	MT40E002_010	C-3	N	NA	N	NA	X	NA	NA
Rock Creek, headwaters to mouth (Missouri River)	MT40E002_090	C-3	P	NA	P	NA	P	NA	NA
Ruby Creek, un-named tributary T25N R25E S21 to mouth (CK Creek)	MT40E002_060	C-3	N	NA	N	NA	X	NA	NA
Ruby Gulch, headwaters to confluence of Alder Gulch	MT40E002_070	C-3	N	NA	N	NA	X	NA	NA
Sullivan Creek, headwaters to mouth (Rock Creek)	MT40E002_110	C-3	N	NA	N	NA	N	NA	NA
Swift Gulch Creek, headwaters to mouth (South Big Horn Creek)	MT40I002_010	B-1	N	N	NA	N	F	F	F

Legend: **F**= Full Support; **P**= Partial Support; **N**= Not Supported; **T**= Threatened; **X**= Not Assessed (Insufficient Credible Data)

Impairment status and impairment list reviews are provided for each waterbody in **Sections 5.0**, **6.0** and **7.0** of this document.

3.3 Applicable Water Quality Standards

Water quality standards include: the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a nondegradation policy that protects the high quality of a waterbody. The ultimate goal of this water quality restoration plan, once implemented, is to ensure that all designated beneficial uses are fully supported and all standards are met. Water quality standards form the basis for the targets described in **Sections 5**, **6** and **7**. Pollutants addressed in this Water Quality Restoration Plan include: metals, cyanide, and pH. This section provides a summary of the applicable water quality standards for each of these pollutants.

3.3.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a waterbody based on the potential of the waterbody to support those uses. Designated Uses or Beneficial Uses are simple narrative descriptions of water quality expectations or water quality goals. There are a variety of “uses” of state waters including: growth and propagation of fish and associated aquatic life; drinking water; agriculture; industrial supply; and recreation and wildlife. The Montana Water Quality Act (WQA) directs the Board of Environmental Review (BER, i.e., the state) to establish a classification system for all waters of the state that includes their present (when the Act was originally written) and future most beneficial uses (Administrative Rules of Montana (ARM) 17.30.607-616), and to adopt standards to protect those uses (ARM 17.30.620-670).

Montana, unlike many other states, uses a watershed based classification system with some specific exceptions. As a result, *all* waters of the state are classified and have designated uses and supporting standards. All classifications include multiple uses and in only one case (A-Closed) is a specific use (drinking water) given preference over the other designated uses. Some waters may not actually be used for a specific designated use, for example as a public drinking water supply; however, the quality of that waterbody must be maintained suitable for that designated use. When natural conditions limit or preclude a designated use, permitted point source discharges or nonpoint source discharges may not make the natural conditions worse.

Modification of classifications or standards that would lower a water’s classification or a standard (i.e., B-1 to a B-3), or removal of a designated use because of natural conditions can only occur if the water was originally mis-classified. All such modifications must be approved by the BER, and are undertaken via a Use Attainability Analysis (UAA) that must meet U.S. EPA requirements (40 CFR 131.10(g), (h) and (j)). The UAA and findings presented to the BER during rulemaking must prove that the modification is correct and all existing uses are supported. An existing use cannot be removed or made less stringent.

The steams or stream segments addressed in this document include designations as B-1, B-3 or C-3. A description of Montana’s applicable surface water classifications and designated beneficial uses for streams in the Landusky TPA are presented in **Table 3-2**.

Table 3-2. Montana Surface Water Classifications and Designated Beneficial Uses Applicable to the Landusky TPA

Classification	Designated Uses
B-1 CLASSIFICATION:	Waters classified B-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-3 CLASSIFICATION:	Waters classified B-3 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-3 CLASSIFICATION:	Waters classified C-3 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers. The quality of these waters is naturally marginal for drinking, culinary, and food processing purposes, agriculture, and industrial water supply.

3.3.2 Standards

In addition to the Use Classifications described above, Montana's water quality standards include numeric and narrative criteria as well as a nondegradation policy.

Numeric surface water quality standards have been developed for many parameters to protect human health and aquatic life. These standards are in the Department Circular DEQ-7 (Montana Department of Environmental Quality, 2010). The numeric human health standards have been developed for parameters determined to be toxic, carcinogenic, or harmful and have been established at levels to be protective of long-term (i.e., lifelong) exposure by water consumption, as well as through direct contact such as swimming.

The numeric aquatic life standards include chronic and acute values that are based on extensive laboratory studies that include a wide variety of potentially affected species, a variety of life stages and durations of exposure. Chronic aquatic life standards are protective of long-term exposure to a parameter. The protection afforded by the chronic standards includes detrimental effects to reproduction, early life stage survival and growth rates. In most cases the chronic standard is more stringent than the corresponding acute standard. Acute aquatic life standards are protective of short-term exposures to a parameter and are not to be exceeded.

High quality waters are afforded an additional level of protection by the nondegradation rules (ARM 17.30.701 et. seq.,) and in statute (75-5-303 MCA). Changes in water quality must be "non-significant" or an authorization to degrade must be granted by the Department. However under no circumstance may standards be exceeded. It is important to note that, waters that meet or are of better quality than a standard are high quality for that parameter, and nondegradation policies apply to new or increased discharges to that the waterbody.

Narrative standards have been developed for substances or conditions for which sufficient information does not exist to develop specific numeric standards. The term "Narrative Standards" commonly refers to the General Prohibitions in ARM 17.30.637 and other descriptive portions of the surface water quality standards. The General Prohibitions are also called the "free from" standards; that is, the surface waters of the state must be free from substances attributable to discharges that impair the beneficial uses of a waterbody. Uses may be impaired by toxic or harmful conditions (from one or a combination of parameters) or conditions that produce undesirable aquatic life. Undesirable aquatic life includes bacteria, fungi and algae.

The standards applicable to the list of pollutants addressed in this document are summarized below.

Metals
Numeric standards for water column metals in Montana include specific standards for the protection of both aquatic life and human health. Acute and chronic criteria have been established for the protection of aquatic life. The criteria for some metals vary according to the hardness of the water. The applicable numeric metals standards (guidelines for aquatic life) for the specific metals of concern in the Landusky TPA are presented in **Table 3-3**. Actual standards for aquatic life at any given hardness are calculated using **Equation 3-1** and **Table 3-4**. The actual standards based on measured hardness values are used in this document to determine standards exceedances, not the guidance from **Table 3-4**. Existing data indicates that other metals are below water quality standards.

Recent studies have indicated that in some streams metals concentrations may vary through out the day because of diel pH and alkalinity changes. In some cases the variation can cross the standard threshold (both ways) for a metal. Montana water quality standards are not time of day dependent.

Table 3-3. Montana Numeric Surface Water Quality Standards Guide for Metals and Cyanide.

Parameter	Aquatic Life (acute) (µL)[a]	Aquatic Life (chronic) (µL)[b]	Human Health (µL)[a]
Aluminum (TR)	750	87	---
Arsenic (TR)	340	150	10
Cadmium (TR)[c]	0.52 @ 25 mg/l hardness	0.097 @ 25 mg/l hardness	5
Chromium (TR)[c]	---	---	100
Copper (TR)[c]	3.79 @ 25 mg/l hardness	2.85 @ 25 mg/l hardness	1,300
Cyanide (TR)	22	5.2	140
Mercury (TR)	0.91	1.7	0.05
Iron (TR)[d]	---	1,000	300d
Lead (TR)[c]	13.98 @ 25 mg/l hardness	0.545 @ 25 mg/l hardness	15
Manganese (TR)[e]	---	---	50
Nickle (TR)	145.21 @ 25 mg/l hardness	16.14 @ 25 mg/l hardness	100
Selenium (TR)	20	5	50
Thallium (TR)	---	---	0.24
Zinc (TR)[c]	37 @ 25 mg/l hardness	37 @ 25 mg/l hardness	2,000

[a] Maximum allowable concentration.
[b] No 4-day (96-hour) or longer period average concentration may exceed these values.
[c] Standard is dependent on the hardness of the water, measured as the concentration of $CaCO_3$ (mg/L) (see **Table 3-5** for the coefficients to calculate the standard).
[d] The concentration of iron must not reach values that interfere with the uses specified in the surface and groundwater standards (17.30.601 et seq. and 17.30.1001 et seq.) The Secondary Maximum Contaminant Level (listed) is based on aesthetic properties such as taste, odor, and staining may be considered as guidance to determine the levels that will interfere with the specified uses.
[e] The concentration of manganese must not reach values that interfere with the uses specified in the surface and groundwater standards (17.30.601 et seq. and 17.30.1001 et seq.). The Secondary Maximum Contaminant Level (listed) is based on aesthetic properties such as taste, odor, and staining may be considered as guidance to determine the levels that will interfere with the specified uses.
Note: TR – total recoverable.

Hardness-based standards for aquatic criteria are calculated using the following equation and are used for determining impairment:

Equation 3-1.

Chronic = exp. {mc[ln(hardness)]+bc} where mc and bc are values from **Table 3-4**

Table 3-4. Coefficients for Calculating Metals Freshwater Aquatic Life Standards (Montana Department of Environmental Quality, 2010).

Parameter	ma (acute)	ba (acute)	mc (chronic)	bc (chronic)
Cadmium	1.0166	-3.924	0.7409	-4.719
Copper	0.9422	-1.700	0.8545	-1.702
Lead	1.273	-1.46	1.273	-4.705
Nickel	0.846	2.255	0.846	0.0584
Zinc	0.8473	0.884	0.8473	0.884

Note: If hardness is <25 mg/L as CaCO3, 25 must be used for the hardness value in the calculation. If hardness is equal or greater than 400 mg/L as CaCO3, 400 mg/L must be used for the hardness value.

Montana also has a narrative standard that pertains to metals in sediment. No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except as permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife (ARM 17.30.623(2)(f)). This narrative standard includes metals laden sediment.

pH

Waterbodies impaired by metals are also sometimes impaired by pH as a result of acid mine drainage. For human health, changes in pH are addressed by the general narrative criteria in ARM 17.30.601 et seq. and ARM 17.30.1001 et seq. For aquatic life, which can be sensitive to small pH changes, criteria are specified for each waterbody use classification. For B-1 waters, ARM 17.30.623 (2)(c) states “Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 8.5 must be less than 0.5 pH unit.” Respectively for B-3 and C-3 waters, ARM 17.30.625 (2)(c) and ARM 17.30.629 (2)(c) state “Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 9.0 must be less than 0.5 pH unit.” “Natural pH outside these ranges must be maintained without change. Natural pH above 7.0 must be maintained above 7.0.”

4.0 DESCRIPTION OF TMDL COMPONENTS

A TMDL is the pollutant loading capacity for a particular waterbody and refers to the maximum amount of a pollutant a stream or lake can receive and still meet water quality standards. Therefore, when a TMDL is exceeded, the waterbody will be impaired.

More specifically, a TMDL is the sum of the allowable loading from all sources to the waterbody. These loads are applied to individual sources or categories of sources as a logical method to allocate water quality protection responsibilities and overall loading limits within the contributing watershed(s). The allocated loads are referred to as waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources. Natural background loading is considered a type of nonpoint source and therefore represents a specific load allocation. In addition, the TMDL includes a Margin of Safety (MOS) that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream. The inclusion of a MOS results in less load allocated to one or more WLAs or LAs to help ensure attainment of water quality standards.

TMDLs are expressed by the following equation which incorporates the above components:

$$\text{TMDL} = \Sigma\text{WLA} + \Sigma\text{LA} + \text{MOS}$$

The allowable pollutant load must ensure that the waterbody being addressed by the TMDL will be able to attain and maintain water quality standards for all applicable seasonal variations in streamflow, and pollutant loading. **Figure 4-1** is a schematic diagram illustrating how numerous sources contribute to the existing load and how the TMDL is defined. The existing load can be compared to the allowable load to determine the amount of pollutant reduction needed.

The major components that go into TMDL development are target development, source quantification, establishing the total allowable load, and allocating the total allowable load to sources. Although the way a TMDL is expressed may vary by pollutant, these components are common to all TMDLs, regardless of pollutant. Each component is described in further detail below.

Section 5 is organized by waterbody and describes the metal pollutants of concern. The section includes a description of the waterbody segments, how the pollutants are is impacting beneficial uses, the information sources and assessment methods to evaluate stream health and pollutant source contributions, water quality target development along with a comparison of existing conditions to targets, quantification of loading from identified sources, the determination of the allowable loading (TMDL) for each waterbody, and the allocations of the allowable loading to sources.

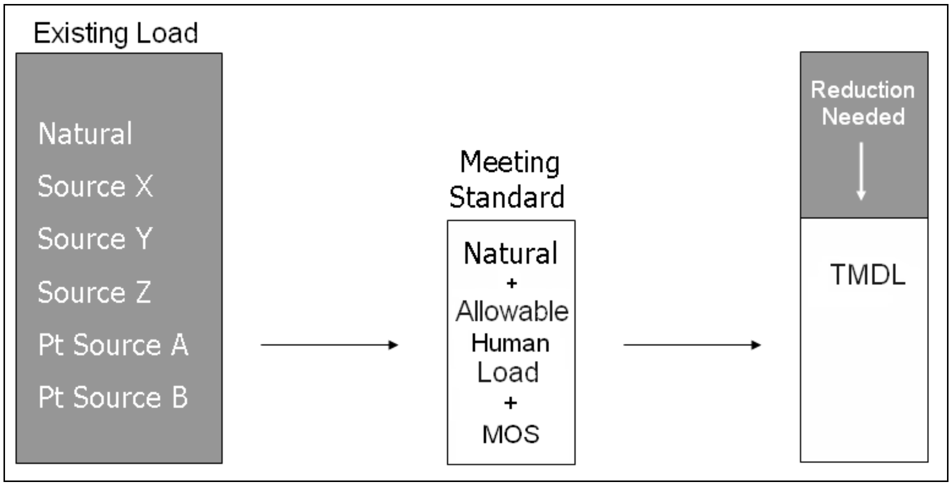

Figure 4-1. Schematic example of TMDL development

4.1 Target Development

Because loading capacity is evaluated in terms of meeting water quality standards, quantitative water quality targets are developed to help assess the condition of the waterbody relative to the applicable standard(s) and to help determine successful TMDL implementation. This document outlines water quality targets for each pollutant of concern in the Landusky TPA. TMDL water quality targets help translate the applicable numeric or narrative water quality standards for the pollutant of concern. For pollutants with established numeric water quality standards, the numeric value(s) within the standard(s) are used as TMDL water quality targets. For pollutants with only narrative standards, the water quality targets provide a site-specific interpretation of the narrative standard(s), along with an improved understanding of impairment conditions. Water quality targets typically include a suite of in-stream measures that link directly to the impacted beneficial use(s) and applicable water quality standard(s). The water quality targets help define the desired stream conditions and are used to provide benchmarks to evaluate overall success of restoration activities. By comparing existing stream conditions to target values, there will be a better understanding of the extent and severity of the problem.

4.2 Quantifying Pollutant Sources

All significant pollutant sources, including natural background loading, are quantified so that the relative pollutant contributions can be determined. Source assessments often have to evaluate the seasonal nature and ultimate fate of the pollutant loading since water quality impacts can vary throughout the year. The source assessment usually helps to further define the extent of the problem by putting human caused loading into context with natural background loading.

A pollutant load is usually quantified for each point source of the pollutant permitted under the Montana Pollutant Discharge Elimination System (MPDES) program. Most other pollutant sources, typically referred to as nonpoint sources, are quantified by source categories such as unpaved roads and/or by land uses such as crop production or forestry. These source categories or land uses can be further divided by ownership such as Federal, State, or private. Alternatively, a sub-watersheds or tributaries approach can be used, whereby most or all sources in a sub-watershed or tributary are combined for quantification purposes.

The source assessments are performed at a watershed scale because all potentially significant sources of the water quality problems must be evaluated. The source quantification approaches may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading (40CFR Section 130.2(I)). Montana TMDL development often includes a combination of approaches depending on the level of desired certainty for setting allocations and guiding implementation activities.

4.3 Establishing the Total Allowable Load

Identifying the TMDL requires a determination of the total allowable load over the appropriate and sensible time period necessary to comply with the applicable water quality standard(s). Although the concept of allowable daily load is incorporated into the TMDL term, a daily loading period may not be consistent with the applicable water quality standard(s) or may not be practical from a water quality management perspective. Therefore, the TMDL will ultimately be defined as the total allowable loading using a time period consistent with the application of the water quality standard(s) and consistent with established approaches to properly characterize, quantify, and manage pollutant sources in the watershed. For example, the TMDL to address acute metals toxicity criteria will include a near-instantaneous loading requirement calculated over a time period of one second (based on standard methods for evaluation flow in cubic feet per second). Chronic metals toxicity criteria will include a daily loading requirement calculated over a 24-hour period.

Where numeric water quality standards exist for a stream, the TMDL or allowable loading, typically represents the allowable concentration multiplied by the flow of water over the time period of interest. This same approach can be applied for situations where a numeric target is developed to interpret a narrative standard and the numeric value is based on an in-stream target concentration of the pollutant of concern.

For narrative standards, there is often a suite of targets based on the parameter causing impairment and related chemical or physical conditions. In many of these situations, it is difficult to link the desired target values to highly variable and often episodic instream loading conditions. In these situations, the TMDL is often expressed as a percent reduction in total loading based on source quantification results and an evaluation of load reduction potential (**Figure 4-1**). The degree by which existing conditions exceed desired target values can also be used to justify a percent reduction value for a TMDL.

Even if the TMDL is preferably expressed using a time period other than daily, an allowable daily loading rate will also be calculated to meet specific requirements of the Clean Water Act. Where this occurs, TMDL implementation and the development of allocations will still be based on the preferred time period as discussed above.

4.4 Determining Allocations

Once the loading capacity (i.e. TMDL) is determined, that total must be divided, or allocated, among the contributing sources. In addition to basic technical and environmental considerations, this step introduces economic, social, and political considerations. The allocations are often determined by quantifying feasible and achievable load reductions associated with the application of reasonable land, soil, and water conservation practices. Reasonable land, soil, and water conservation practices generally include Best Management Practices (BMPs), but additional conservation practices may be required to achieve compliance with water quality standards and restore beneficial uses. It is important to note that implementation of the TMDL does not conflict with water rights or private property rights. **Figure 4-2** contains a schematic diagram of how TMDLs are allocated to different sources using WLAs for point sources and LAs for natural and nonpoint sources. Although some flexibility in allocations is possible, the sum of all allocations must meet the water quality standards in all segments of the waterbody.

Under the current regulatory framework for development of TMDLs, flexibility is allowed in the expression of allocations in that *"TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure."* Allocations are typically expressed as a number, a percent reduction (from the current load), or as a surrogate measure, such as a percent increase in canopy density for temperature TMDLs.

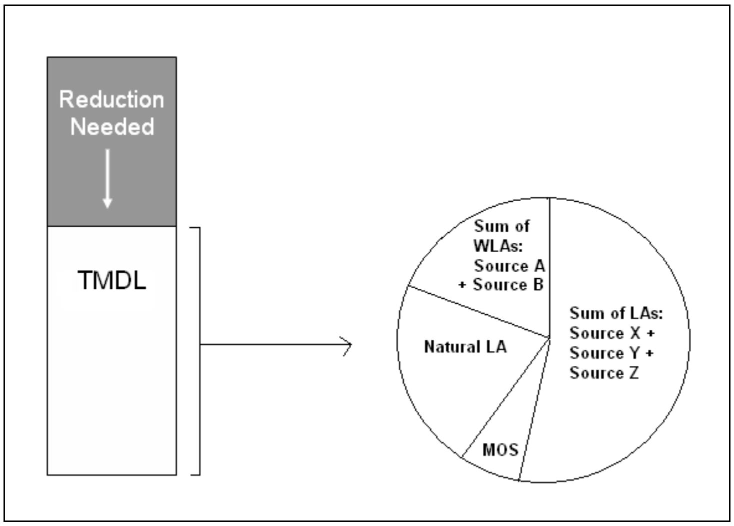

Figure 4-2. Schematic diagram of TMDL and allocations

Incorporating a margin of safety (MOS) is a required component of TMDL development. The MOS accounts for the uncertainty between pollutant loading and water quality and is intended to ensure that load reductions and allocations are sufficient to sustain conditions that will support beneficial uses. The MOS may be applied implicitly by using conservative assumptions in the TMDL development process or explicitly by setting aside a portion of the allowable loading (United States Environmental Protection Agenc, 1999).

5.0 METALS TMDL COMPONENTS

This portion of the document focuses on metals impairment of water quality. It describes: 1) the mechanisms by which metals impair beneficial uses of those streams, 2) the specific stream segments of concern, 3) the presently available data pertaining to metals impairments in the watershed, 4) the various contributing sources of metals based on recent data and studies, and 5) the metals TMDLs and allocations.

5.1 EXCESS METALS EFFECTS ON BENEFICIAL USES

Elevated metals concentrations in the Landusky TPA are related to the weathering of rock types that contain metal sulfide minerals. Examples of these minerals include iron sulfides such as pyrite (FeS_2), lead sulfides such as galena (PbS), and copper sulfides such as chalcocite (Cu2S). Exposure of metal sulfide minerals to oxygen (O_2) and water (H_2O) results in a series of chemical reactions that produce sulfuric acid and metal oxide precipitates. The following series of equations describes the oxidation of pyrite, the most common sulfide mineral at the Zortman and Landusky mines:

(1) $FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{+2} + 2\ SO4^{2-} + 2\ H^+$

(2) $Fe^{+2} + ¼O_2 + H^+ \rightarrow Fe^{+3} + 2H^+$

(3) $Fe^{+3} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+$

(4) $FeS_2 + 15/4\ O_2 + 7/2\ H_2O \rightarrow 2H_2SO_4 + Fe(OH)_3$

The second and third equations are often accelerated by the activity of iron oxidizing bacteria such as *Thiobacillus ferrooxidans*, which commonly occurs in surface and groundwater. The fourth equation summarizes first three and shows the formation of sulfuric acid (H_2SO_4) and iron oxide ($Fe(OH)_3$). Iron oxide often causes turbidity in surface water and causes the reddish coating of stream bottom sediments often associated with pyrite oxidation. The increased surface water acidity associated with sulfide oxidation increases the solubility of other metals such as copper, lead, and arsenic. The acid generation and metal contamination caused by metal sulfide oxidation are commonly referred to as "acid rock drainage" or ARD. **Figure 5-1** shows the effects of ARD on water quality in Swift Gulch Creek.

Figure 5-1. ARD-related iron oxide turbidity and substrate coating in Swift Gulch Creek

Waterbodies with metals concentrations exceeding the aquatic life and/or human health standards can impair support of numerous beneficial uses including aquatic life, both warm and cold water fisheries, drinking water, and agriculture. Elevated of metals concentrations can have toxic, carcinogenic, or bioconcentrating effects on aquatic organisms. Humans and wildlife can suffer acute and chronic health effects from consuming metal contaminated drinking water or fish tissue. Because elevated metals can be toxic to plants and animals, metal contamination may damage agricultural irrigation or stock water uses.

5.2 Stream Segments of Concern

A total of 11 waterbody segments in the Landusky TPA were listed as impaired due to metals-related causes on the 2010 Montana 303(d) List (**Table 5-1**). All 2010 303(d) Listings are included in **Table 1-1** and the beneficial use support status of listed segments is presented in **Table 3-1**. Metals-related listings include aluminum, arsenic, cadmium, chromium, copper, cyanide, iron, lead, mercury, nickel, selenium, thallium, sulfates, and zinc. Although pH and cyanide are not metals, they are address in this document because of their common association with metal contamination from mining sources.

Table 5-1. Waterbody segments in the Landusky TPA with metals-related impairments on the 2010 303(d) List

Waterbody ID	Stream Segment	Probable Causes of Impairment
MT40E002_050	**ALDER GULCH**, headwaters to mouth (Ruby Creek)	Cadmium, Copper, Lead, Mercury, Selenium, Zinc, pH
MT40M001_011	**BEAVER CREEK**, headwaters to Fort Belknap Reservation boundary	Cadmium, Lead, Iron
MT40I001_030	**SOUTH BIG HORN CREEK**, Zortman Mine to Fort Belknap Reservation boundary	Aluminum, Arsenic, Cadmium, Nickel, Zinc
MT40I001_040	**KING CREEK**, headwaters to Fort Belknap Reservation boundary	Selenium
MT40I001_050	**LODGE POLE CREEK**, headwaters to Fort Belknap Reservation boundary	Cadmium, Mercury
MT40E002_100	**MILL GULCH**, headwaters to mouth (Rock Creek)	Copper, Mercury, Selenium, pH
MT40E002_010	**MONTANA GULCH**, headwaters to mouth (Rock Creek)	Arsenic, Cadmium, Copper, pH
MT40E002_090	**ROCK CREEK**, headwaters to mouth (Missouri River)	Cadmium, Copper Lead, Mercury, Selenium, Zinc, pH
MT40E002_060	**RUBY CREEK**, un-named tributary T25N R25E S21 to mouth (CK Creek)	Aluminum, Cadmium, Copper Lead, Mercury, Selenium, Zinc, pH
MT40E002_070	**RUBY GULCH**, headwaters to confluence of Alder Gulch	Cadmium, Chromium, Copper, Lead, Mercury, Zinc, pH
MT40I002_010	**SWIFT GULCH CREEK**, headwaters to mouth (South Big Horn Creek)	Aluminum, Arsenic, Cadmium, Copper, Cyanide, Iron, Lead, Nickel, Selenium, Thallium, Zinc, pH

5.3 Information Sources and Assessment Methods

The following information sources were used to assess pollutant sources and characterize pollutant loading in the planning area:

- The DEQ monitoring and assessment database for the Landusky TPA
- The Zortman-Landusky (Z-L) ACCESS relational database (Spectrum Engineering, Inc., 2005)
- Final Environmental Impact Statement (EIS), Zortman and Landusky Mines, 1996, and supporting documents (United State Department of the Interior, et al., 1996)
- Montana state agency (DEQ, MBMG) active and abandoned mine databases
- Federal agency databases of water chemistry, biology, and stream discharge
- Geographical Information System (GIS) data for geology, soil, landcover and land use layers
- 2009 National Agricultural Imagery Program (NAIP) Aerial photos
- Water balance and loading estimates reported by contract consultants.

The DEQ monitoring and assessment record (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010) is the basis for stream impairment listings. Most of the metals impairments are based on water column chemistry data collected from the late 1980s through the mid-1990s. Metals impairment listings for 10 of the 11 listed segments are based predominantly on records from the DEQ STOREASE database, dating from 1977 through 1994. For several streams, STOREASE data are supplemented by records from the Z-L ACCESS database for the period 2001 through 2003. The most recently updated assessment record is that for Swift Gulch Creek. It includes ZL ACCESS data for the period 1985-2007. Sediment chemistry data is available for a single site on upper Beaver Creek collected during a DEQ field assessment in July, 2005.

The Microsoft Z-L ACCESS database is maintained by Spectrum Engineering, Inc. under contract with the DEQ It is the largest source of water quality data for the planning area. Originally assembled in 2002, the ZL ACCESS database contains all baseline and mine permit compliance data collected by Zortman Mining, Inc. (ZMI), the mine operator from 1978 through 1998. The database also contains the results of all reclamation and water treatment monitoring since mining ended. It is regularly updated by Spectrum, Inc. as monitoring continues. Field and analytical protocols for the sample results and measurements in the ZL ACCESS database are described in **Section 3.5** of "Final Engineering/Cost Analysis for Water Management at the Zortman and Landusky Mines, Phillips County, Montana" (Spectrum Engineering, Inc., 2006).

The ZL ACCESS database contains nearly 193,000 analysis results and measurements from about 600 monitoring locations. Most of these records consist of surface and groundwater quality analyses, flow records and groundwater elevation measurements. TMDL development is based on a subset of this data that includes surface water chemistry and flow measurements obtained during the most recent 10-year period of record for selected monitoring sites. **Table 5-2** identifies the monitoring stations and data timeframes selected to describe the existing water quality condition for each of the 11 metals-listed streams, plus Sullivan Creek. The locations of these monitoring sites are shown in **Figure 5-2**.

Table 5-2. Monitoring stations and data timeframes used to characterize existing water quality conditions of impaired stream segments

Waterbody ID	Stream Segment	Monitoring Station IDs	Monitoring Timeframe
MT40E002_050	Alder Gulch	Z-2, Z-8, Z-16,	1990-1998
MT40M001_011	Beaver Creek	Z-31, Z-39, M41BVRC03	1990-2005
MT40I001_030	South Big Horn Creek	L-48, L-48A	2002-2010
MT40I001_040	King Creek	503, L-5, L-39	2000-2010
MT40I001_050	Lodge Pole Creek	Z-7, Z-29	1990-1998
MT40E002_100	Mill Gulch	506, L-7, L-22, L-36	1990-2010
MT40E002_010	Montana Gulch	L-16, L-47, L-2, 591	2000-2010
MT40E002_090	Rock Creek	L-1, L-4, L-23, L-29	1990-2008
MT40E002_060	Ruby Creek	Z-17, Z-32	1990-2010
MT40E002_070	Ruby Gulch	667, Z-15, Z-100, Z-1B	1990-2010
MT40E002_110	Sullivan Creek	505, 595, D-4, L-37	2000-2010
MT40I002_010	Swift Gulch Creek	BKSS-2, BKSS-3, BKSS-9, L-19, L-49, M37SWFGC01,	2000-2010

Although not listed in 2010 as metals-impaired, Sullivan Creek water quality is also affected by mining.

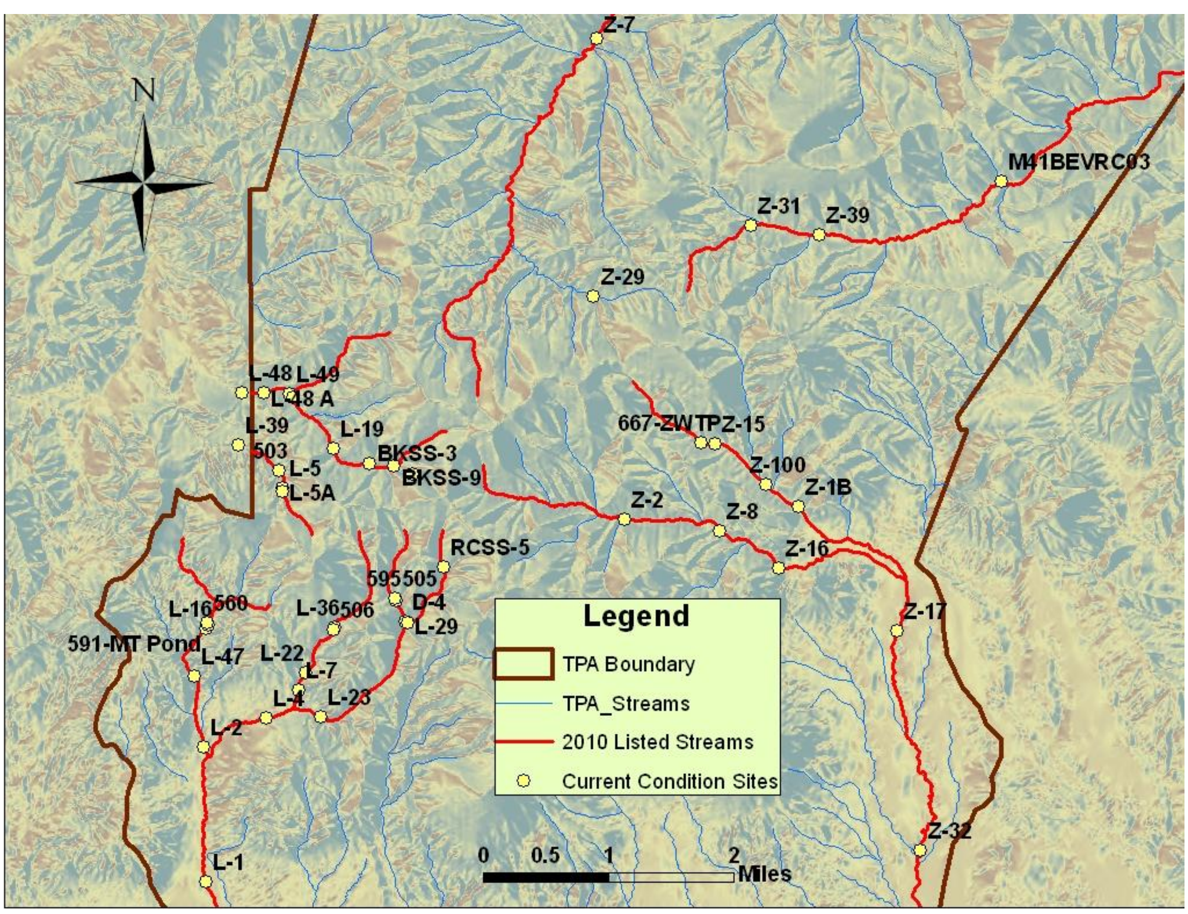

Figure 5-2. Monitoring sites selected as representing current water quality conditions

The criteria applied in selecting the **Table 5-2** sites include the following:

- Location to reflect water quality along as much of the main channel length of listed segments as possible
- Location bracketing significant mining sources
- The currency of the data record
- Number of analysis results and measurements

A second set of monitoring stations is selected to describe water quality in areas having minimal or no upstream mining disturbance. The purpose in separating these sites is to obtain an estimate of natural background water quality. Past assessments of water quality at the Zortman and Landusky mines document differences in metal concentrations caused by the degree of bedrock mineralization. The mineralization process alters bedrock chemistry through changes in the temperature, pressure, or pH of circulating hydrothermal fluids. Mineralization frequently occurs in fracture or shear zones or along contacts between differing rock types. The alteration increases local bedrock concentrations of metal elements that are the focus of mining activity. Mineralization in the Little Rock Mountains has mainly occurred parallel to shear zones within the bedrock core of the mountain range. The 16 surface water monitoring sites selected to estimate background surface water quality are listed in **Table 5-3**.

Table 5-3. Monitoring stations and data timeframes used to characterize natural background water quality conditions of impaired stream segments

Waterbody ID	Stream Segment	Monitoring Station IDs	Monitoring Timeframe
MT40E002_050	Alder Gulch	Z-60, Z-61, Z-62,AGSS-10	1996-1998
MT40M001_011	Beaver Creek	Z-27	1990-2005
MT40I001_030	South Big Horn Creek	L-21	1986-2008
MT40I001_040	King Creek	L-40	1994-1996
MT40I001_050	Lodge Pole Creek	Z-28, Z-30	1990-1998
MT40E002_100	Mill Gulch	L-40, RCSS-5	1994-1998
MT40E002_010	Montana Gulch	L-40	1994-1996
MT40E002_090	Rock Creek	Z-60, Z-61, Z-62, RCSS-5	1996-1998
MT40E002_060	Ruby Creek	Z-9, Z-52, Z-60, Z-61, Z-62, AGSS-10, RGSS-1, RGSP-1	1994-1998
MT40E002_070	Ruby Gulch	Z-9, Z-52, RGSS-1, RGSP 1	1994-1997
MT40E002_110	Sullivan Creek	L-40, Z-60, Z-61, Z-62, RCSS-5	1994-1998
MT40I002_010	Swift Gulch Creek	L-21, L-41, L-45	1986-2008

Figure 5-3 shows the location of the background sites in relation to the mineralized shear zones that were the focus of mining at Zortman and Landusky. The sites are generally in portions of the stream drainages more remote from mining disturbances. The **Table 5-3** sites which are included in the Zortman and Landusky mine water classification system developed by Osborne and Gallagher (2001), are classified as “Headwaters Background”, “Mineralized Syenite Background”, and “Non-Mineralized Syenite Background.” Although the shear zones shown in **Figure 5-3** are concentrated in headwater positions, other such zones occur throughout the core of the Little Rockies range. Thus, the metal sulfide mineralogy can potentially affect water quality at other locations and at lower elevations.

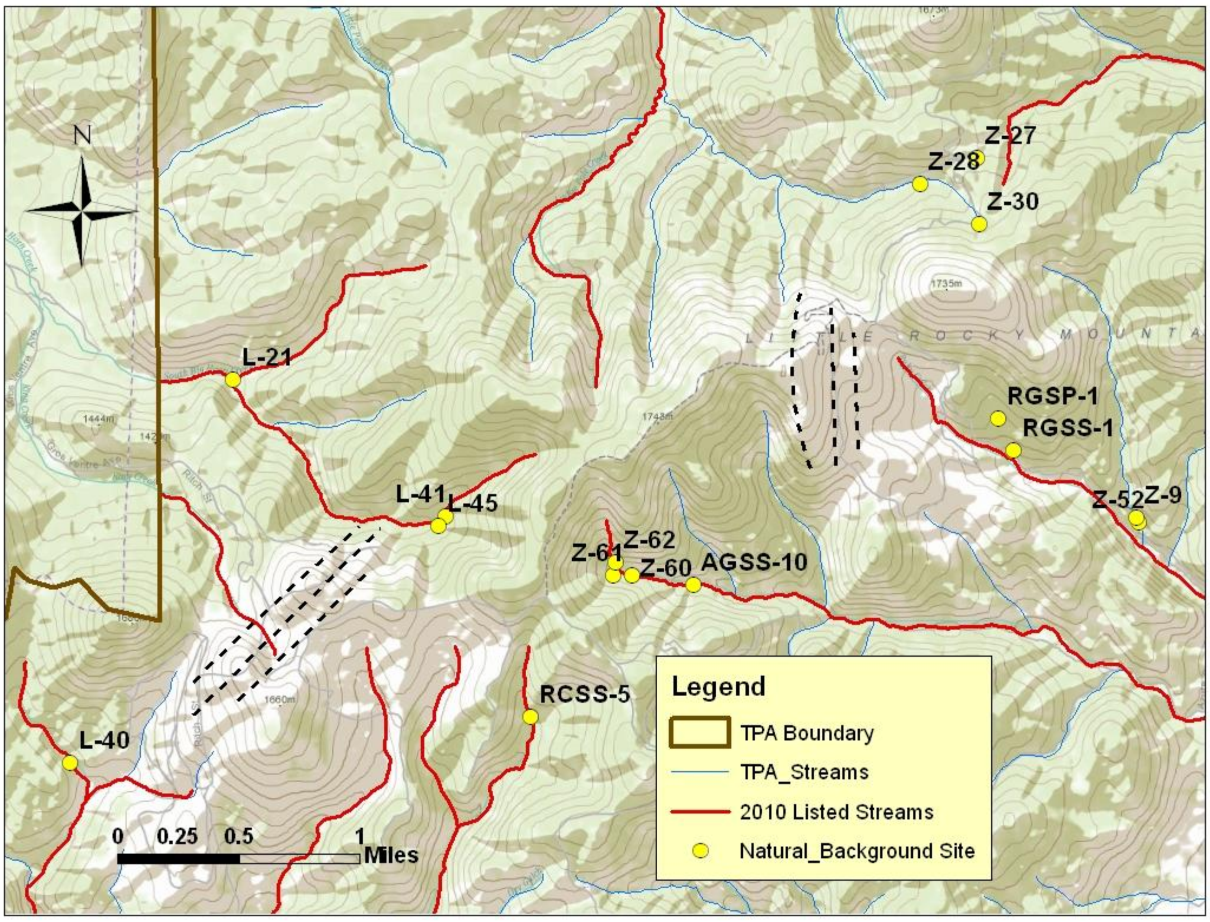

Figure 5-3. Locations of sites representing natural background water quality relative to bedrock shear zones in the Zortman (upper right) and Landusky (lower left) mine areas.

Older data are used in this document when data from the past decade are not available. The most recent surface water chemistry data for Alder Gulch, Beaver Creek, and Lodge Pole Creek are dated from 1990 through 1998. The most recent records for the remaining eight streams are dated from 2000 through 2010, but data age can vary by site.

Recent data is generally of higher quality because of lower method detection limits, more consistent collection methods, and more accurate and standardized analysis procedures. The most recent data also reflects the effects of significant surface reclamation activities that occurred at the Zortman and Landusky mines from 1999 through 2005. STORET and NWIS data for the period 1985-1994 are also available for several streams and have been incorporated into the ZL ACCESS database

The number of water quality monitoring records used in TMDL analysis is further reduced by excluding results for hardness-dependent metals when the sample lacks a hardness value. Thus, the need for TMDLs is based only upon results for which the corresponding numeric criteria can be calculated from hardness.

In older water chemistry data, the detection limits of analytical methods are frequently higher than the numeric criteria used to determine impairment. Such records cannot be used for target comparisons and are omitted from use support and TMDL analyses. Despite these subtractions, the Z-L ACCESS database remains the most comprehensive source of water chemistry and flow data. **Appendix B** contains the raw water quality data for metals and related parameters, by listed segment, used for TMDL development.

In addition to the ZL ACCESS database, Spectrum Engineering, Inc. supplied a number of digital and hard copy maps of the Zortman and Landusky mine areas. They identify monitoring point locations, hydrogeologic features, topography and the extent of underground mine workings. Other geographic information includes locations of above ground mine facilities, water capture and treatment systems, leach pads, dikes, pit areas, waste storage areas and roadways.

Abandoned mine databases maintained by DEQ and MBMG were used to better understand the locations and scales of historic mining, particularly in Alder and Ruby gulches. Geologic GIS data and recent aerial photography were used to locate potential metals sources and to understand the hydraulic connections between mine disturbances and the local stream system.

Since metals concentrations in surface waters often vary seasonally, data seasonality is also important for estimating loading. Springtime flows that typically have a large snowmelt or precipitation component commonly dilute metals concentrations during April, May and June. Summer, fall and winter flows have a larger groundwater component that provides less dilution. The operation of several subsurface capture systems demonstrate the substantial groundwater contributions to surface water metals loading. Examining water quality data under both high and low flow conditions is necessary to account for seasonal variability. The flow values used to estimate seasonal loading will vary by stream because of the large differences in drainage area among the listed streams.

Based on a combined assessment of source locations and water quality data, the potential sources of metals loading in the Landusky TPA include:

- Natural background loading
- Abandoned mines
- Surface and groundwater loading from areas disturbed by ZMI operations (1979 -1998).
- Point sources of wastewater from treatment plants

5.3.1 Natural Background Water Quality

Natural background water quality typically has neutral to slightly acidic pH, is low in dissolved solids, and has low sulfate and metals concentrations. Sites Z-60, Z-61, and Z-62, that are located in the relatively undisturbed headwater tributaries of Alder Gulch, represent natural background conditions for several nearby segments within the southern portion of the planning area. **Table 5-4** summarizes the 16 records for these sites for parameters that reflect ARD conditions. The records date from 1996 to 1998 and show minimal effects of ARD.

Table 5-4. Summary statistics for water quality data from sites Z-60, Z-61 and Z-62 showing minimal ARD effects in upper Alder Gulch

Summary Statistic	Total Hardness (mg/L)	Total Dissolved Solids (mg/L)	Sulfate (mg/L)	pH	Iron (µg/L)	Zinc (µg/L)
Minimum	11	40	9	6.6	380	< 5
Median	15	60	13	7.0	605	20
Maximum	18	74	65	7.8	780	30
Count	16	12	16	16	12	16

The median pH is neutral. All hardness values are less than 25 milligrams per liter (mg/L). The median sulfate concentration is less than 20 mg/L. All iron and zinc concentrations meet water quality standards.

Four sites in the upper reaches of Beaver (Z-27), Lodge Pole (Z-28 & Z-30) and South Big Horn creeks (L-21) are also remote from mining disturbances and represent background metals loading conditions within the northern portion of the planning area. **Table 5-5** summarizes the water quality of these sites.

Table 5-5. Summary statistics for water quality data from sites Z-21, Z-27, Z-28, and Z-30 showing minimal ARD effects in upper Beaver, Lodge Pole and South Big Horn creeks

Summary Statistic	Total Hardness (mg/L)	Total Dissolved Solids (mg/L)	Sulfate (mg/L)	pH	Iron (µg/L)	Zinc (µg/L)
Minimum	25	25	1.8	5.5	5	1
Median	95	83	14	7.5	175	5
Maximum	267	611	56	12.2	2680	80
Count	111	50	91	96	84	84

Although there are elevated values for the some parameters in **Table 5-5**, the median values represent surface water unaffected by sulfide oxidation from mining sources.

The remaining nine sites assumed to represent natural background conditions include the following:

- Sites L-41 and L-45 in upper Swift Gulch Creek
- Sites L-40 and RGSS-5 in the upper portions of Montana Gulch and Rock Creek, respectively
- Four sites (Z-9, Z-52, RGSP-1, RGSS-1) in unnamed tributaries draining undisturbed areas north of Ruby Gulch.

Table 5-6 summarizes the seasonal differences in water chemistry for the 16 background sites. High flow conditions are for sampling events from April through June; low flow conditions are for sampling events from July through December. Except for iron concentration, the median values are lower during high flows when dilution is provided by precipitation or snowmelt. The higher iron concentration during high flow may reflect a larger sediment contribution to loading of total recoverable iron.

Table 5-6. Comparison of high and low flow summary statistics for ARD-related parameters and flow from 18 monitoring sites representing natural background conditions

Summary Statistics	Flow (GPM)	Total Hardness (mg/L)	TDS (mg/L)	SO4 (mg/L)	pH (S.U.)	Fe (µg/L)	Zn (µg/L)
High Flow Statistics							
Minimum	1	9	25	2	5.5	10	5
Median	**21**	**56**	**82**	**11**	**7.3**	**400**	**10**
Maximum	1350	249	611	98	12.2	2680	80
Count	70	96	91	85	85	81	86
Low Flow Statistics							
Minimum	0.19	35	52	5	6.9	15	5
Median	**1.4**	**198**	**235**	**42**	**7.6**	**160**	**10**
Maximum	4039	297	351	134	8	1670	20
Count	8	22	21	17	22	9	9

A study by Gabelman and others (2005) of pre-mine water quality in Swift Gulch Creek concluded that pre-mining conditions were generally not affected by ARD. Ferricrete, an iron-cemented conglomerate rock type, occurs adjacent to some stream courses in the Zortman-Landusky area. The presence of ferricrete is evidence of sulfide oxidation prior to mining. The age of the ferricrete deposits in the Zortman-Landusky area indicates formation during prehistoric weathering of metal sulfides exposed during glaciation, landslides, or other significant erosion events. Therefore, some degree of ARD occurred periodically in the area because of weathering caused by climate and rapid erosional episodes (Gabelman, et al., 2005).

All of the streams with metals impairments have been affected by mining to some extent. When possible, natural background metals loading will be accounted for separately from mining sources. However, for aluminum, cadmium, copper and lead, the water quality records for sites representing natural background conditions contain values that occasionally exceed the water column criteria established in Circular DEQ-7. Therefore, natural background sources cannot always be assumed to meet metals target concentrations in the water column. In cases where there is no clear distinction between natural background and human-caused loading sources, composite allocations to natural background and mining sources may be needed until monitoring can clarify the natural background loading contribution and allocations can be adjusted through adaptive management.

5.3.2 Abandoned Mines and Associated Wastes

Mining in the Little Rocky Mountains began with the discovery of placer gold in Alder Gulch in 1884. News of the find sent about 2000 miners into the area within a month (Burlingame and Toole, 1957). The boundary of an area set aside for Indian tribes was modified to accommodate mining and the southern boundary of the Fort Belknap Reservation was modified in 1896. Placer mining gave way to development of the first load claims at the Julie, August and Gold Bug properties within the Landusky mine area. Ore was processed using a small stamp mill and mercury amalgamation until late in 1902.

The mining camp of Zortman was established in 1903 with operation of a cyanide mill in Alder Gulch that processed ore from the Alabama and Pole Gulch mines until 1908. The Ruby, Mint and Divide claims supplied ore for the Ruby Gulch Mill, a cyanide leaching plant that was constructed in 1905 and operated until destroyed by fire in 1913. It was rebuild the following year and reached its peak production during 1917. Operations of the Ruby Gulch Mill were suspended in 1918 and the mill again burned in 1923. Charles Whitcomb, with a number of associates, consolidated the Landusky mining properties and formed the Little Ben Mining Company that operated a large cyanide mill in upper King Creek. Whitcomb and other investors opened another cyanide mill in Ruby Gulch in 1935 that operated until being shut down by the War Production Board in 1942. Later attempts to reopen the mine faltered after the war and serious mining efforts ceased in 1951 (Murray, 1978).

The Pegasus Gold Corporation operated the Zortman and Landusky mines from 1979 through 1998 through its wholly owned subsidiary, ZMI, Inc. Operating permits for two open pit mines with cyanide heap leaching operations were obtained from the former Montana Department of State Lands in 1979. Between 1979 and 1990 the Landusky Mine permit boundary expanded from 530 to 1,287 acres; the disturbed area expanded from 256 to 814 acres. During the same period at the Zortman Mine, the permit boundary expanded from 619 to 961 acres, with the disturbed area expanding from 273 to 401 acres. Pegasus began chapter 11 proceedings in 1998. Since then, the Bureau of Land Management (BLM) and DEQ have implemented mine closure, reclamation and wastewater treatment operations at both mine areas. Details of the timing and sequence of reclamation and waste treatment operations at the mines are described in Spectrum Engineering, Inc. (2006).

DEQ and MBMG databases identify about 45 abandoned mines within the Landusky TPA. None have been given a high priority ranking and many have been obscured or covered by more recent surface mining by ZMI, Inc. (**Appendix A, Figure 15**). Abandoned mine disturbances include both placer and lode operations that range from small hillslope disturbances to the more extensive alluvial workings such as those in Alder Gulch and lower Swift Gulch Creek. Abandoned mine effects on surface water quality are variable.

Environmental data describing individual abandoned mines is typically insufficient to guide specific load allocations. Where data is adequate, abandoned mine sites are considered as unpermitted point sources and assigned distinct wasteload allocations (WLA). Contributions from other abandoned mine sources are included in composite WLAs for mining sources. This approach assumes that metals loading reductions can be accomplished with remediation of these properties and surrounding mine disturbances.

5.3.3 Point Sources

Four wastewater treatment plants operate as point sources under authority of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) through the BLM. Treatment of ARD affected wastewater by pH adjustment with hydrated lime is occurring at three plants located at the Landusky Mine, Zortman Mine and in the Swift Gulch Creek drainage. The Zortman plant began operation on June 10th, 1994. It discharges treated water to surface water in Ruby Gulch. The Landusky plant, that began operation on October 1st, 1997, discharges to surface water into Montana Gulch. The Swift Gulch Creek plant began a seasonal (June through November) operations during 2010. Treated wastewater discharges to Swift Gulch Creek downstream of the plant. Since 2005, a fourth plant provides biological removal of cyanide, selenium and nitrates from leach pad drainage piped from both the Zortman and Landusky mines. Treated water is discharged either to surface water in Montana Gulch or to a 204-acre land disposal area located between Goslin Gulch and Ruby Creek about one mile south of the town of Zortman. **Figure 5-4** illustrates the locations of the treatment plant point sources and the Goslin Flats land disposal area.

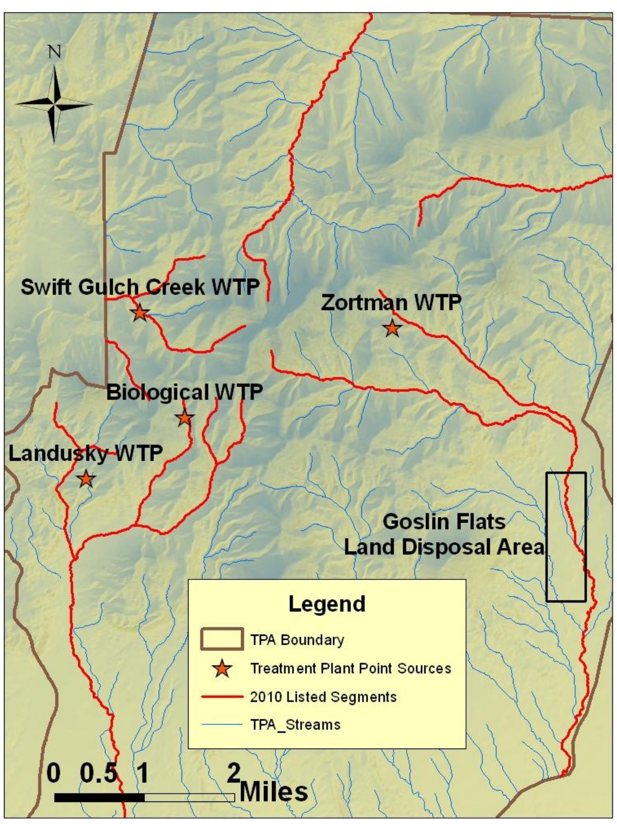

Figure 5-4. Wastewater treatment plant and Goslin LAD point source locations.

After use of CERCLA authority for reclamation and treatment plant operations, the two Montana Pollutant Discharge Elimination System (MPDES) permits, for the Landusky Mine (MT0024864) and Zortman mine (MT0024856) were terminated on July 1, 2004.

5.4 Water Quality Targets

The established Montana numeric water quality criteria are adopted as the water quality targets for metal and cyanide pollutants. These values are published in Circular DEQ-7 (Montana Department of

Environmental Quality, 2010). Circular DEQ-7 contains acute and chronic aquatic life criteria, designed to protect aquatic life uses, and the human health criteria, designed to protect drinking water uses. Attainment of *chronic* aquatic life water quality criteria is based on an average water quality metals concentration over a 96 hour period. The one-hour average concentration in surface water may not exceed the a*cute* aquatic life water quality criteria more than once in any three year period. DEQ has determined that the allowable exceedance rate for the acute criteria is equivalent to 10 percent of samples collected using a typical monitoring design that includes representative and independent samples under both high and low flow conditions. No exeedances are allowed at twice the acute aquatic life criteria. No exeedances of human health criteria are allowed. Where the numeric criteria apply to protection of both aquatic life and human health, the most restrictive value is adopted as the water quality target.

Metals and Cyanide
Water quality targets include the acute and chronic aquatic life and human health criteria for dissolved aluminum, and total recoverable concentration of arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, thallium, and zinc (Montana Department of Environmental Quality, 2010). The aquatic life criteria for several metals are dependent upon water hardness. The acute and chronic aquatic life criteria for cadmium, copper, lead, nickel, and zinc increase with increasing hardness. **Table 3-3** contains the aquatic life and human health criteria for these metals at a hardness value of 25 mg/L. **Table 3-3** also contains the aquatic life and human health criteria for cyanide and those metals not affected by water hardness including aluminum, arsenic, chromium (total), mercury, iron, manganese, selenium and thallium.

The human health criterion given in Circular DEQ-7 for iron (300 µg/L) and manganese (50 µg/L) are based on secondary maximum contaminant levels (MCL) established by EPA to prevent aesthetic issues with taste, odor, or staining. These values are considered as guidance to determine interference with the specified uses after conventional water treatment. It is assumed that the concentrations of iron and manganese present in listed waterbodies after conventional treatment would not consistently exceed the guidelines. Therefore, the chronic aquatic life criterion of 1,000 µg/L is the water quality target for iron. Since there are no aquatic life criteria for manganese and no manganese listings in the Landusky TPA, no targets or TMDLs are developed in this document for manganese.

5.4.1 Supplemental Indicators

Sulfate
Montana currently has no numeric water quality criteria for sulfate. Sulfate criteria development has focused on use classification categories that include drinking water. In the Landusky TPA, these are the streams in categories B-1 and B-3 (see **Table 3-1**). Use classifications are broadly applied in the Landusky TPA. All streams draining north into the Milk River are classified as either B-1 or B-3; streams draining south to the Missouri River are classified as C-3. A DEQ review of sulfate effects on aquatic life recommended a concentration range of 200-250 mg/L for western Montana streams, based on toxicity testing of salmonid fishes in British Columbia (Denisger, 1998). The sulfate range recommended for protection of aquatic vegetation is 50-100 mg/L. Regardless of the current classification, all stream reaches in the mountainous portion of the planning area probably supported salmonid fish and associated aquatic life prior to mining. Water temperature and dissolved solids (including sulfate) concentrations naturally increase with the transition from a mountain to a prairie setting. Thus, sulfate concentrations in low elevation reaches are inherently higher than those of upland headwater reaches.

Natural background concentrations of sulfate are low in planning area surface waters compared with waters affected by mining. The median values for high and low flow sulfate concentration are 11 and 42 mg/L respectively (**Table 5-6**). Mining activity and associated sulfide oxidation have caused wide sulfate ranges in affected surface waters. The typical range is from the median values in **Table 5-6** to several thousand mg/L. **Figure 5-5** illustrates this range for water quality in Swift Gulch Creek that began to deteriorate during the early 1990s as of local groundwater contaminated beneath the Landusky Mine pit entered the stream through a series of springs. The wide fluctuation in sulfate concentration after 2000 is the dilution effect of spring snowmelt and precipitation.

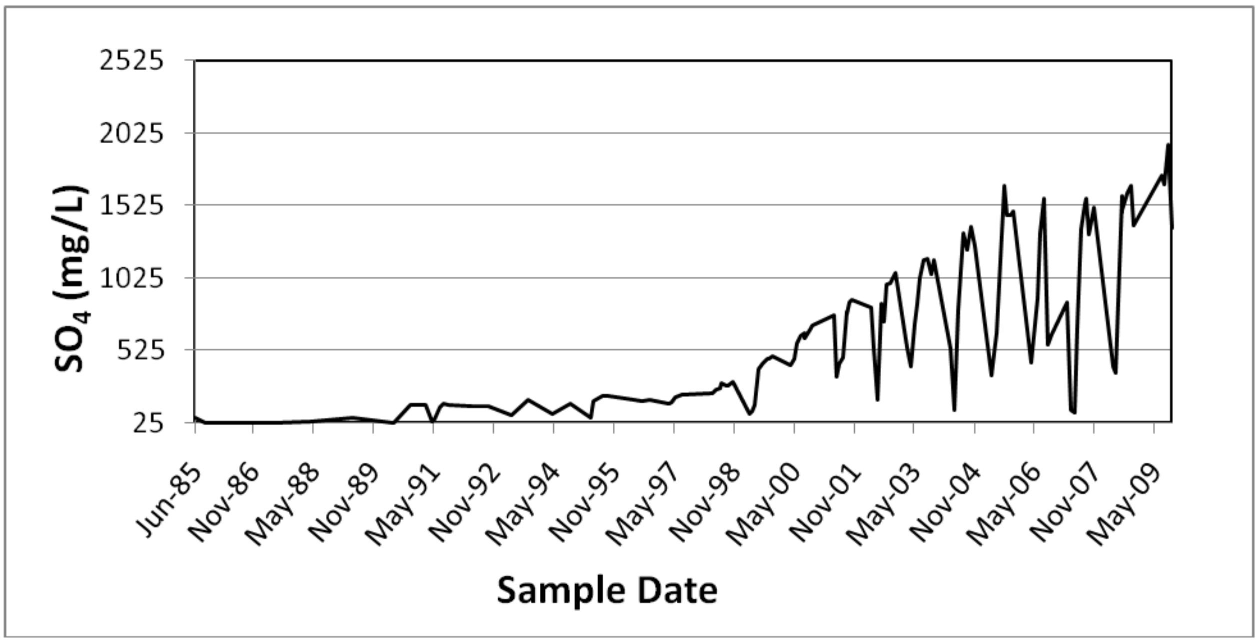

Figure 5-5. Surface water sulfate monitoring record for site L-19 in Swift Gulch Creek.

The natural background sulfate levels in the mountainous portion of the planning area are commonly an order of magnitude less than the 200-250 mg/L range recommended for protection of trout in B-classified streams in western Montana. Considering the inherently low sulfate concentrations for mountain stream reaches, and the expected higher background sulfate concentrations within prairie reaches, a sulfate concentration of 200mg/L is selected as a maximum value for aquatic life protection in the Landusky TPA.

Metals in Sediment

The general prohibitions in Montana's water quality standards (ARM 17.30.637) apply to additions of pollutants in sediment at harmful or toxic concentrations. Although sediment chemistry data is sparse, sediment concentration guidelines are used here as supplemental indicators of water quality problems. The National Oceanic and Atmospheric Administration (NOAA) has developed Screening Quick Reference Tables that contain metals concentration guidelines for freshwater and marine sediments (Buchman, 2008). The screening criteria, developed from a variety of toxicity studies, are expressed as Probable Effects Levels (PELs) in **Table 5-7**.

Table 5-7. Screening criteria for sediment metals concentrations used as supplemental indicators.

Metal Parameter	PEL (µg/g dry weight)
Arsenic	17
Cadmium	3.53
Chromium	90.0
Copper	197
Lead	91.3
Nickel	36
Zinc	315

PELs represent the sediment concentrations above which toxic effects frequently occur. PELs are used here as a screening tool to identify potential impacts to aquatic life.

Macroinvertebrate Metrics

Macroinvertebrate metrics have been developed to document the relationship between water quality and the health of this aquatic life form. Macroinvertebrate assessment models in use by the DEQ Water Quality Planning Bureau are the Multimetric Indices (MMI) for mountain, low valley, and prairie landscapes, and the River Invertebrate Prediction and Classification System (RIVPACS) that is applied to all streams regardless of physical setting. These macroinvertebrate metrics are useful water quality targets that apply directly to waterbodies in Montana as indicators of beneficial use support for aquatic life.

Macroinvertebrate assessment sites in the Landusky TPA fit into the "Low Valley" index category that applies to locations having elevations less than 1,700 meters (5,577 feet). The minimum use support threshold score for this site category is 48; the RIVPACS model specifies a minimum use support score of 0.80 that applies to all Montana streams. These values are used as supplemental indicators of aquatic life use support.

5.4.2 Target Summary
The metals targets and supplemental indicators are summarized below in **Table 5-8**.

Table 5-8. Targets and Supplemental Indicators for the Landusky TPA

Target Parameter	Criterion
Water Column Pollutant Concentration	Montana Water Quality Standards, Circular DEQ 7 (Montana Department of Environmental Quality, 2010)
Supplemental Indicators	**Criterion**
Water Column Sulfate Concentration (mg/L)	200
NOAA Quick Reference Table for Inorganics in Freshwater Sediment	Probable Effects Limits (PELs) (Buchman, 2008)
Macroinvertebrate Multi Metric Index (MMI), Low Valley Index Score	48
River Invertebrate Prediction and Classification System (RIVPACS) Score	0.8

5.4.3 Targets, Supplemental Indicators, and the Need for TMDLs
The decisions to complete metals and cyanide TMDLs are based on the combined influence of the following factors:

- Degree of compliance with numeric water column criteria and supplemental indicators
- The presence of human-caused loading sources
- The current pollutant listing status of the segment
- Availability of pollutant concentration and flow data for high and low flow conditions
- The temporal distribution of exceedances within the monitoring record
- The age of the dataset

Compliance with targets and supplemental indicators, the presence of sources, and the current listing status for a parameter are the primary factors influencing TMDL development decisions. The seasonality requirement for TMDLs makes high and low flow data availability another primary decision factor. Though not essential for TMDLs, information about the trend of target exceedances in the monitoring record helps to identify additional impairment causes, recognize developing or remediated sources, and refine monitoring plans. On a case-by-case basis, a valid impairment listing for a pollutant with a sparse, outdated, or inconclusive data record frequently supports TMDL development. The following scenarios are examples where combined consideration of the decision factors indicates the need for metals TMDLs.

1. The most restrictive metals criterion for aquatic life support is exceeded in greater than 10 percent of analysis results for samples from a listed segment with known sources
2. One or more analysis results is more than double the acute aquatic life criteria
3. One or more results exceed the human health criterion during the most recent 10-year period
4. The aquatic life criteria are exceeded in less than 10 percent of samples, exceedances are concentrated among the most recent data, and known sources are present in a listed segment
5. Water column concentration targets are met, supplemental indicators are commonly exceeded, and known human-caused sources occur in the drainage of a listed segment.

Additional monitoring may be recommended in lieu of TMDLs where only supplemental indicators are exceeded, causes are unlisted, and the effects of sources on water quality are unknown or unclear. The following examples are scenarios in which additional monitoring and source assessment would preclude TMDL development.

1. All analysis results for a listed pollutant consist of non-detections, and method detection limits exceed the water quality criteria
2. Recent data indicate no target exceedances for a listed segment, sources are present, data is not sufficient to evaluate seasonal loading.
3. Natural background concentrations of either listed or unlisted metals consistently exceed aquatic life criteria, supplemental indicators are below suspect levels, and sources are absent or remote from surface waters.

5.4.4 Achievability of Water Quality Targets
With the bankruptcy of ZMI in 1998, the BLM and DEQ essentially became operators responsible for reclamation and water treatment at the Zortman and Landusky mines. Because these operations control releases of hazardous substances onto and from BLM administered lands, the reclamation and water treatment operations are classified as removal actions under CERCLA, with the BLM as lead federal

agency. The BLM and DEQ are jointly conducting the removal actions according to a 2006 Action Memorandum that specifies attainment of Applicable or Relevant and Appropriate Requirements (ARARs) of federal and state laws. The applicable ARARs are listed in Appendix 4 of the Engineering Evaluation/Cost Analysis for Water Management at the Zortman and Landusky Mines, Phillips County Montana (Spectrum Engineering, Inc., 2006). The applicable ARARs include the Montana Water Quality Act and Montana regulations establishing ambient water quality standards, including those specified in Circular DEQ-7. The Action Memorandum states that the removal actions will attain ARARs “to the extent practicable considering the exigencies of the situation.” The most significant obstacles to meeting water quality ARARs are funding limitations, the wide variability in the volume of water needing treatment, and access limitations preventing year round treatment plant operation.

From 1994 through 2010 the annual precipitation measured at the Zortman and Landusky weather stations has varied from 15 to 30 inches. Water balance calculations by Osborne (2003) estimated that an average of 44 percent of precipitation at the mine sites infiltrates the land surface. The leach pad liners capture about 26 million gallons per year at Zortman and about 70 million gallons per year at Landusky. Periodic large spring rainstorms, or rainstorms combined with spring snowmelt periodically exceed the capacities of both leach pad liners and drainage capture systems. Such conditions have required decisions allowing temporarily bypasses of drainage capture systems. Systems with better water quality have been allowed to bypass treatment in favor of routing more polluted waters to the treatment plants. Storage capacity overflows and resulting bypass strategies have caused applicable ARARs to be exceeded. Variable precipitation and storm intensity combine with an annual funding shortfall to force compromises in ARAR compliance.

The annual operating and maintenance costs for the capture and treatment of mine-impacted water are about $1.5 million. The surety companies reached an agreement with the DEQ to fund reclamation and water treatment to the limits of the surety bonds. Only $731,321 is available annually under the water treatment surety bond, leaving an annual funding shortfall of about $670,000. The BLM has provided an average of $100,000 annually. Thus, operation and maintenance of the water treatment system has a current annual shortfall of about $570,000 (Spectrum Engineering, Inc., 2006). Several funding sources will combine to provide a project trust fund of $33.9 million beginning in 2018. The trust can provide perpetual funding if assumed annual return and inflation assumptions are correct. If the annual return is less and inflation greater than assumed, an eventual long-term funding shortfall could result.

The physical setting of the Swift Gulch Creek water treatment plant in a steep, confined drainage with heavy winter snowfall prevents year round treatment plant operations. Under current operations, bypasses are required when inflow exceeds the plant’s 800 gpm capacity or when the volume of the sludge setting ponds is exceeded. Despite efforts to provide for timely sludge removal, seasonal discharges of ARD-affected water exceeding water quality ARARs are anticipated in Swift Gulch Creek.

Under the current Memorandum of Understanding between the BLM and DEQ, DEQ and its contractors will continue to operate, maintain and monitor the Zortman, Landusky, and Swift Gulch Creek treatment plants, and the leach pad treatment and disposal system under CERCLA authority, using funds available from the surety companies. The BLM will continue with reclamation actions and consult with DEQ on the need for any new removal actions necessary to protect BLM lands. The BLM will provide funding to supplement surety payments as allowed by the BLM budgeting process. Cooperation between the two agencies will continue with the goal of meetings water quality ARARs as consistently as possible, considering available funding and physical site limitations.

5.5 Existing Conditions and Departures from Water Quality Targets

The water quality record for each stream impaired by metals or cyanide is assessed in terms of the targets and supplemental indicators listed above in **Table 5-8**.

The first step in the evaluation process is to identify a subset of the monitoring sites contained in the Z-L ACCESS database for each stream segment. These are the sites identified above in **Section 5.3**. The objectives of the selection process are to:

1. Identify sites that reflect a broad sampling time frame that captures the effects of tributary inflows and changing downstream sources
2. Identify sites that reflect the effects of increasing downstream flow on pollutant concentrations
3. Identify sites that reflect minimal human caused loading to gain perspective on the degree of impairment in the segment.

Monitoring results from sites representing current conditions are compared to targets and supplemental indicators to determine the need for TMDLs. Data for listed metals are evaluated first, followed by a review of data for other metals with notable target departures.

The stream by stream review of metals loading sources and comparison of water quality data to targets and supplemental indicators is contained in **Appendix F** for the 12 listed streams. The target departure analyses and TMDL conclusions are summarized below for each segment in **Tables 5-9 through 5-20**.

Table 5-9. Metals decision factors and TMDL conclusions for Alder Gulch

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Parameter Listing in 2010	TMDL Decision	Qualifying Notes
Cadmium	Y/Y	Y	Y	Y	Y	Y	N	Y	Cd TMDL	Most recent data is 1998
Copper	Y/Y	Y	Y	Y	Y	Y	N	Y	Cu TMDL	Most recent data is 1998
Lead	Y/N	N	Y	Y	Y	Y	N	Y	Pb TMDL	One exceedance 1995-1998
Mercury	N/N	N	Y	Y	Y	Y	N	Y	Hg TMDL	Most MDLs Exceed WQ Criteria
Selenium	N/N	Y	Y	Y	Y	Y	Y	Y	Se TMDL	Single Exceedance in 1992; None since in 75 results
Zinc	Y/Y	Y	Y	Y	Y	Y	N	Y	Zn TMDL	Most recent data-1998

Table 5-10. Metals decision factors and TMDL conclusions for Beaver Creek

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Parameter Listing in 2010	TMDL Decision	Qualifying Notes
Cadmium	Y/Y	N	N	N	Y	Y	Y	Y	No Cd TMDL	No exceedance since 1990
Iron	N/NA	NA	NA	N	Y	Y	Y	Y	No Fe TMDL	No exceedance at selected sites
Lead	Y/N	N	Y	N	Y	Y	Y	Y	Pb TMDL	No exceedance since 1994

Table 5-11. Metals decision factors and TMDL conclusions for South Big Horn Creek

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Parameter Listing in 2010	TMDL Decision	Qualifying Notes
Aluminum	Y/N	N	N	Y	Y	N	N	Y	Al TMDL	Limited dataset
Arsenic	N/N	N	Y	Y	Y	N	Y	Y	As TMDL	Single HH Exceedance
Cadmium	Y/N	N	Y	Y	Y	N	Y	Y	Cd TMDL	Increasing Cd trend
Iron	Y/NA	NA	NA	Y	Y	N	N	N	Fe TMDL	Background high flow exceedance
Nickel	Y/N	N	Y	Y	Y	N	Y	Y	Ni TMDL	Increasing Ni trend
Zinc	Y/Y	Y	Y	Y	Y	N	Y	Y	Zn TMDL	Increasing Zn trend

Table 5-12. Metals decision factors and TMDL conclusions for King Creek

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Parameter Listing in 2010	TMDL Decision	Qualifying Notes
Arsenic	N/N	N	Y	Y	Y	N	N	N	As TMDL	High flow HH exceedance
Cadmium	Y/N	N	Y	Y	Y	N	Y	N	Cd TMDL	Increasing Cd trend
Selenium	Y/Y	Y	Y	Y	Y	N	N	Y	Se TMDL	Decreasing trend at L-39

Table 5-13. Metals decision factors and TMDL conclusions for Lodge Pole Creek

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Parameter Listing in 2010	TMDL Decision	Qualifying Notes
Cadmium	N	N	N	N	Y	Y	N	Y	Cd TMDL	Aging dataset
Mercury	N	N	N	Y	Unknown	Y	N	Y	Hg TMDL	High MDLs

Table 5-14. Metals decision factors and TMDL conclusions for Mill Gulch

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Paramete r Listing in 2010	TMDL Decision	Qualifying Notes
Copper	Y/Y	Y	Y	Y	Y	Y	N	Y	Cu TMDL	High flow background CAL exceedance
Lead	N/N	N	N	Y	Y	Y	N	Y	No Pb TMDL	Aging dataset at L-7
Mercury	N/N	N	Unknown	Y	Y	Y	N	Y	Hg TMDL	Aging dataset High MDLs
Selenium	Y/Y	Y	Y	Y	Y	Y	N	Y	Se TMDL	Aging dataset at L-7

Table 5-15. Metals decision factors and TMDL conclusions for Montana Gulch

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Parameter Listing in 2010	TMDL Decision	Qualifying Notes
Arsenic	N/N	N	NA	Y	Y	N	Y	Y	As TMDL	Decreasing trend at MT Pond outfall
Cadmium	Y/N	Y	NA	Y	Y	N	Y	**Y**	Cd TMDL	Increasing trend at MT Pond outfall
Copper	N/N	N	NA	Y	Y	N	Y	Y	No Cu TMDL	Increasing trend at MT Pond since late 2005
Cyanide	Y/N	Y	NA	Y	Y	N	Y	N	CN TMDL	Increasing trend at MT Pond since mid-2004
Nickel	Y/N	N	NA	Y	Y	N	Y	N	Ni TMDL	Increasing trend at MT Pond since late 2005
Selenium	Y/Y	Y	NA	Y	Y	N	Y	N	Se TMDL	Increasing trend at MT Pond since mid-2004
Zinc	N/N	Y	NA	Y	Y	N	Y	N	Zn TMDL	Increasing trend at MT Pond since March, 2005

Table 5-16. Metals decision factors and TMDL conclusions for Rock Creek

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Parameter Listing in 2010	TMDL Decision	Qualifying Notes
Cadmium	Y/N	N	Y	Y	Y	Y	N	Y	Cd TMDL	Aging dataset
Copper	Y/Y	Y	N	Y	Y	Y	N	Y	Cu TMDL	Aging dataset
Lead	Y/N	N	Y	Y	Y	Y	N	Y	Pb TMDL	High MDLs
Mercury	N/N	N	Unknown	Y	Y	Y	N	Y	Hg TMDL	High MDLs
Selenium	N/N	N	N	Y	Y	Y	N	Y	Se TMDL	Old data, previous listing, sources
Zinc	N/N	Y	N	Y	Y	Y	N	Y	Zn TMDL	Single result > 2(AAL)

Table 5-17. Metals decision factors and TMDL conclusions for Ruby Gulch

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Parameter Listing in 2010	TMDL Decision	Qualifying Notes
Aluminum	Y/Y	Y	NA	Y	Y	N	N	N	Al TMDL	Small sample size, High MDLs
Cadmium	Y/Y	Y	Y	Y	Y	N	N	Y	Cd TMDL	
Chromium	N/N	N	N	Y	Y	N	N	Y	Cr TMDL	Listing from old data with one HH exceedance in groundwater
Copper	N/N	Y	N	Y	Y	N	N	Y	No Cu TMDL	Results > 2(AAL) are 1995-1997 data
Cyanide	Y/N	Y	N	Y	Y	N	Y	N	CN TMDL	Pulses of CN in Zortman WWTP outfall 2003-2005
Lead	N/N	N	Y	Y	Y	N	N	Y	No Pb TMDL	HH exceedance in 1995-1997 data
Mercury	N/N	N	Y	Y	Y	N	N	Y	Hg TMDL	High MDLs prevent drinking water assessment
Selenium	Y/N	N	N	Y	Y	N	Y	Y	Se TMDL	Long-term decrease in Zortman WWTP loading
Zinc	N/N	Y	Y	Y	Y	N	N	Y	No Zn TMDL	HH exceedance in 1995-1997 data

Table 5-18. Metals decision factors and TMDL conclusions for Ruby Creek

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Paramete r Listing in 2010	TMDL Decision	Qualifying Notes
Aluminum	Unknown	N	NA	Y	Y	N	N	Y	Al TMDL	High MDL
Cadmium	Y/Y	Y	Y	Y	Y	N	N	Y	Cd TMDL	Small dataset pre-2000
Copper	Y/Y	Y	Y	Y	Y	N	N	Y	Cu TMDL	Small dataset pre-2000
Lead	Y/N	N	N	Y	Y	N	N	Y	Pb TMDL	High MDLs
Mercury	Y	N	Y	Y	Y	N	N	Y	Hg TMDL	High MDLs
Selenium	Y/Y	N	N	Y	Y	N	N	Y	Se TMDL	8 of 9 results pre-2000
Zinc	Y/Y	Y	Y	Y	Y	N	N	Y	Zn TMDL	3 of 7 results pre-2000

Table 5-19. Metals decision factors and TMDL conclusions for Sullivan Gulch

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Parameter Listing in 2010	TMDL Decision	Qualifying Notes
Cadmium	Y/N	N	Y	Y	Y	N	N	N	Cd TMDL	
Iron	Y/NA	NA	NA	Y	Y	N	N	N	Fe TMDL	
Lead	Y/N	N	Y	Y	Y	N	N	N	Pb TMDL	
Selenium	N/N	N	N	Y	Y	N	Y	N	Se TMDL	Recent trend of CAL exceedance in old dataset
Zinc	Y/Y	Y	N	Y	Y	N	N	N	Zn TMDL	

Table 5-20. Metals decision factors and TMDL conclusions for Swift Gulch Creek

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Parameter Listing in 2010	TMDL Decision	Qualifying Notes
Aluminum	Y/N	Y	NA	Y	Y	Y	N	Y	Al TMDL	Aging Dataset, High MDLs
Arsenic	N/N	N	Y	Y	Y	Y	Y	Y	As TMDL	Increasing As Trend
Cadmium	Y/Y	Y	Y	Y	Y	Y	Y	Y	Cd TMDL	Increasing Cd Trend, High MDLs
Copper	Y/Y	Y	Y	Y	Y	Y	Y	Y	Cu TMDL	Increasing Cu Trend, High MDLs
Cyanide	N/N	Y	N	Y	Y	Y	Y	Y	CN TMDL	Decreasing trend
Iron	Y/NA	NA	NA	Y	Y	Y	Y	Y	Fe TMDL	Increasing trend
Lead	N/N	N	N	Y	Y	Y	Y	Y	No Pb TMDL	Decreasing trend

Table 5-20. Metals decision factors and TMDL conclusions for Swift Gulch Creek

Pollutant Parameter	CAL/AAL Exceedance Rate > 10%	Results Twice the AAL Criterion	HH Criterion Exceeded	Supplemental Indicators Suggest Impairment	Human-Caused Sources Present	Variable Flow Data Available	Notable Water Quality Trend	Parameter Listing in 2010	TMDL Decision	Qualifying Notes
Nickel	Y/N	N	Y	Y	Y	Y	Y	Y	Ni TMDL	Increasing trend
Selenium	N/N	N	N	Y	Y	Y	N	Y	No Se TMDL	
Thallium	NA/NA	NA/NA	Unknown	Y	Unknown	Y	N	Y	Tl TMDL	High MDLs
Zinc	Y/Y	Y	Y	Y	Y	Y	Y	Y	Zn TMDL	Increasing trend

5.5.1 TMDL Development Summary

Twelve stream segments in the Landusky TPA require the development of 60 TMDLs for metals and cyanide (**Table 5-21**). The metals of concern include aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, thallium and zinc. Cyanide TMDLs will be developed for Montana Gulch, Ruby Gulch and Swift Gulch Creek. As indicated in **Table 5-21**, 7 of the 12 streams are listed in 2010 for pH. They include Alder Gulch, Mill Gulch, Montana Gulch, Rock Creek, Ruby Gulch, Ruby Creek, and Swift Gulch Creek. Surrogate metal parameters have been selected to address the impairments caused by pH. Cadmium will serve as the pH surrogate in Alder Gulch, Montana Gulch, Rock Creek, Ruby Gulch, Ruby Creek and Swift Gulch Creek; copper will serve as the pH surrogate in Mill Gulch.

Several parameters that were not listed as impairment causes in the 2010 Integrated Report were added to the list of needed TMDLs based on data reviews. All five metal causes for Sullivan Gulch are new listings. Iron is a new cause listing for South Big Horn Creek. Arsenic and Cd are new listings for King Creek. Cyanide, Ni, Se and Zn are new listings in Montana Gulch. Aluminum and cyanide are new listings for Ruby Gulch. Conversely, the data review identified several pollutants included in the 2010 Integrated Report that are no long causing impairment. These include Cd and Fe in Beaver Creek, Pb in Mill Gulch, Cu in Montana Gulch, Cu, Pb, and Zn in Ruby Gulch, and Se and Pb in Swift Gulch Creek.

Table 5-21. Streams requiring TMDLs for metal and cyanide pollutants.

Waterbody Segment ID	Waterbody Segment	2010 Integrated Report Listings (metals-related)	Verified Target Exceedances and TMDL Developed
MT40E002_051	Alder Gulch	Cd, Cu, Hg, Pb, Se, Zn, pH	Cd, Cu, Hg, Pb, Se, Zn
MT40M001_011	Beaver Creek	Cd, Fe, Pb	Pb
MT40I001_030	South Big Horn Creek	Al, As, Cd, Ni, Zn	Al, As, Cd, Fe, Ni, Zn
MT40I001_040	King Creek	Se	As, Cd, Se
MT40I001_050	Lodge Pole Creek	Cd, Hg	Cd, Hg
MT40E002_100	Mill Gulch	Cu, Hg, Pb, Se, pH	Cu, Hg, Se
MT40E002_010	Montana Gulch	As, Cd, Cu pH	Cd, CN, Ni, Se, Zn
MT40E002_090	Rock Creek	Cd, Cu, Hg, Pb, Se, Zn, pH	Cd, Cu, Hg, Pb, Se, Zn
MT40E002_060	Ruby Creek	Al, Cd, Cu, Hg, Pb, Se, Zn, pH	Al, Cd, Cu, Hg, Pb, Se, Zn
MT40E002_070	Ruby Gulch	Cd, Cr, Cu, Hg, Pb, Se, Zn, pH	Al, Cd, CN, Cr, Hg, Se
MT40E002_110	Sullivan Gulch	Not metals listed	Cd, Fe, Pb, Se, Zn
MT40I002_010	Swift Gulch Creek	Al, As, Cd, Cu, CN, Fe, Pb, Ni, Se, Ti, Zn, pH	Al, As, Cd, Cu, CN, Fe, Pb, Ni, Tl, Zn

5.6 TMDLs

As explained in **Section 4.0**, TMDLs are the maximum amount of each pollutant parameter that a stream can assimilate without exceeding water quality standards. A stream's ability to assimilate metal pollutants is based on its hardness (for hardness-dependent metals) and its capacity to dilute metal concentrations with increased flow. Stream discharge and water hardness both vary seasonally. Therefore, established TMDLs must provide seasonal protection of beneficial uses.

TMDLs are calculated according to *Equation 1*:

Equation 1: $TMDL = (X)*(Y)*(0.0054)$,
where:

TMDL = Total Maximum Daily Load in lbs/day for pollutants of concern
X = the most restrictive water quality target (typically either the CAL or HH criterion in µg/L)
Y = streamflow in cubic feet per second (cfs)
0.0054 = a conversion factor to obtain loading in units of pounds per day.

As discussed in **Section 5.4**, where the numeric criteria apply to protection of both aquatic life and human health, the most restrictive value is adopted as the water quality target and inserted as the value for "X" in the above equation. Using a CAL criterion that is based on a 96-average value to calculate a daily load provides an implicit margin of safety in the calculated TMDL.

Although the TMDLs are based on HH or CAL criteria, the AAL criteria are also water quality targets applied as an instantaneous instream concentration that shall not be exceeded (see **Section 4.3**). For example, an instantaneous spike in a pollutant concentration during a capture system bypass may exceed the acute criterion while remaining in compliance with the chronic standard. The TMDL will ultimately be defined as the total allowable loading using a time period consistent with the application of the most appropriate numeric water quality criterion. Remediation required to eliminate pollutant loading that exceeds the chronic standards will often mitigate more extreme short duration exceedances of acute criteria.

5.6.1 TMDLS for Non-Hardness Dependent Metals and Cyanide

The toxicity of several metal elements and the cyanide are independent of water hardness. The TMDLS for these substances can be illustrated graphically using Equation 1 above with the most restrictive water quality criterion substituted for the value of "X", and stream discharge in cubic feet per second (cfs) substituted for the value of "Y". **Figure 5-6** shows the graphs of the TMDLs for Fe, As, Se, CN, Tl, and Hg based on the most restrictive water quality criterion for each parameter over a range of stream discharge common in the Landusky TPA.

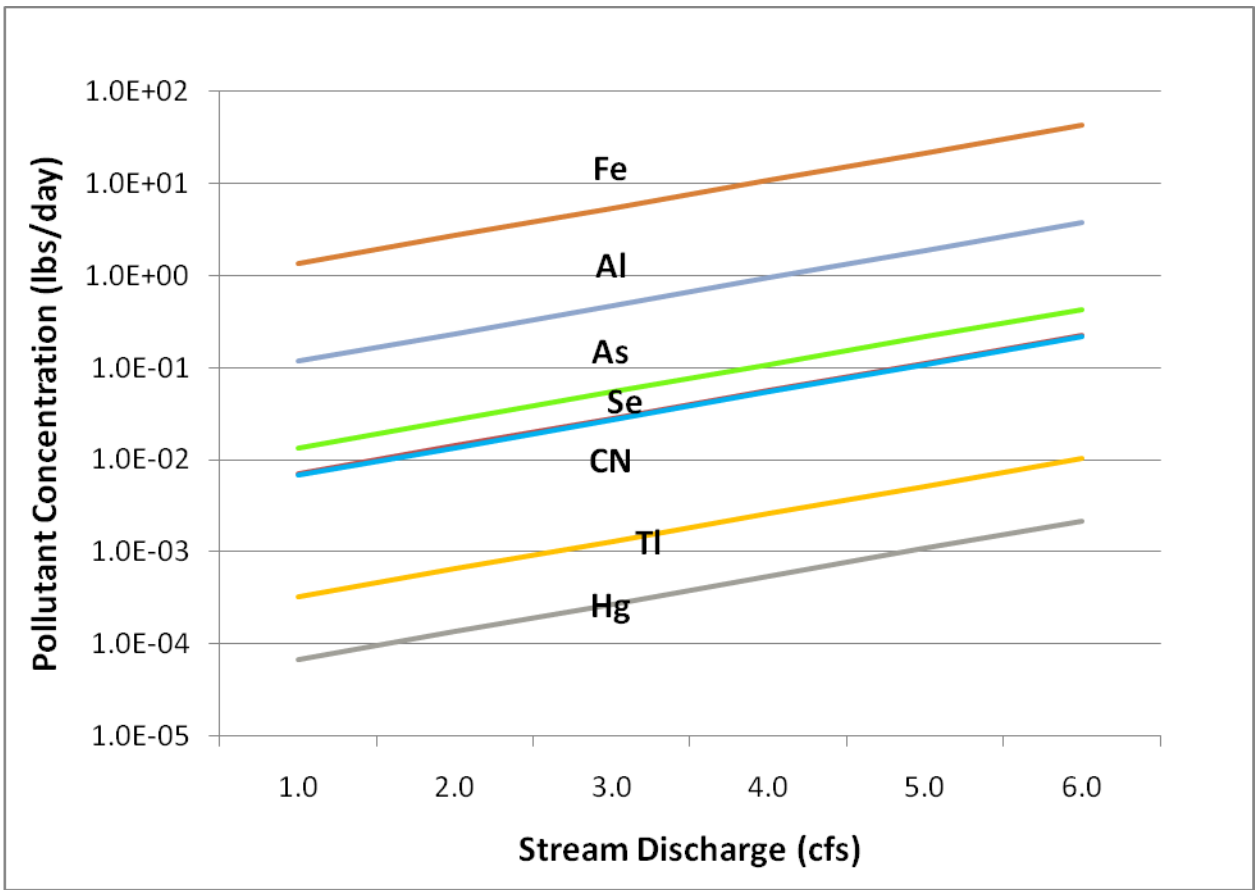

Figure 5-6. Graphs of TMDLs (lbs/day) for iron (Fe), aluminum (Al), arsenic (As), selenium (Se), cyanide (CN), thallium (Tl), and Mercury (Hg) with increasing stream discharge

The **Figure 5-6** graphs are based on the CAL criterion for Fe (1,000 µg/L), the CAL for Al (87 µg/L), the HH criterion for As (10 µg/L), the CAL criterion for Se (5 µg/L), the CAL criterion for CN (5.2 µg/L), the HH criterion for Tl (0.24 µg/L), and the HH criterion for Hg (0.05 µg/L). The TMDL graphs in **Figure 5-6** apply to all aluminum, arsenic, cyanide, iron, mercury, selenium, and thallium TMDLs within this document.

5.6.2 Example TMDLS for Metals and Cyanide for Listed Streams

Table 5-22 contains example TMDLs, also calculated using *Equation 1*, for the 12 waterbody segments in the Landusky TPA requiring one or more metals or cyanide TMDLs. The example high- and low-flow TMDLs apply at a selected monitoring station on each stream. High flow values in the table are medians of flow measurements greater than the 50th percentile flow for the site. Low flows are medians of flow measurements less than the 50th percentile. The hardness values, used to calculate the hardness-dependent metals targets, are mean values for each flow condition. The water quality targets are the most restrictive among the CAL, AAL, and HH criteria. Example TMDLs in the table are in units of pounds per day. Monitoring station selection is guided by availability of flow and hardness data and a station location that reflects loading from significant sources. The calculated example TMDLs represent the maximum load (lbs/day) of each pollutant that each waterbody can receive without exceeding applicable water quality standards for the specified flow and hardness. The raw data for the metals of concern are included in **Appendix B**.

Table 5-22 also contains calculated percent reductions in loading needed to meet metals and cyanide TMDLs under high and low flow conditions in each stream. The calculated reductions for each stream and flow condition are based on the portion of dataset that exceeds water quality targets. Pollutant loading in the planning area occurs in pulses caused by periodic high precipitation events or by temporary capture system bypasses that can result from either high flows or system malfunctions. Pulses of high loading are often separated by extended periods of minimal loading due to low flows or proper capture system function and wastewater treatment. Therefore, it is common for datasets to consist of a series of elevated metals values followed by a series of low values or values less than analytical MDLs. Although the dataset may contain a sufficient number of large exceedances to be listed as metals impaired, the mean or median values for such datasets are commonly less than water quality targets. Therefore, the reductions in **Table 5-22** are based on the portion of each dataset where exceedances are most numerous. The number in parentheses following s each reduction percentage identifies the dataset percentile above which the exceedances are most concentrated and the loading reduction is most needed. For example, the first line in **Table 5-22** specifies a 97% high flow reduction and a 99% low flow reduction in Cd loading to Alder Gulch. In each case, the reduction applies to dataset values above the 45^{th} percentile. In other words, Cd target exceedances for Alder Gulch are concentrated in the upper 55 percent of sample values in both the high-flow and low-flow datasets. Load reductions are not required for datasets that contain no target exceedances, and a value of “0” is entered in the table in these instances.

Table 5-22. Example metals TMDLs for waterbodies in the Landusky TPA

Stream Segment (Segment ID)	Station	Discharge (cfs)		Hardness		Metal	Target Concentration (µg/L)		TMDL (lbs/day)		Percent Load Reduction Based on Sampled Target Exceedance	
		High flow	Low flow	High flow	Low flow		High flow	Low flow	High flow	Low flow	High flow	Low flow
Alder Gulch (MT40E002_050)	Z-8	1.5	0.05	140	300	Cadmium	0.35	0.61	0.003	0.0002	97 (45)	99 (45)
						Copper	12.44	23.85	0.10	0.006	91 (55)	96 (85)
						Lead	4.88	12.88	0.040	0.003	93 (54)	7 (90)
						Zinc	159.34	303.94	1.290	0.082	50	80
				NA		Mercury	0.05	0.05	0.00041	0.000014	90	90
						Selenium	5	5	0.041	0.00135	97	0
Beaver Creek (MT40M001_011)	Z-31	0.42	0.05	83	109	Lead	2.51	3.55	0.0057	0.00096	88	0
South Big Horn Creek (MT40I001_030)	L-48	0.49	0.03	227	400	Cadmium	0.50	0.76	0.001	0.0001	92	90
						Nickel	104.37	168.54	0.280	0.027	65	60
						Zinc	239.98	387.83	0.635	0.063	65	90
				NA		Aluminum	87	87	0.230	0.014	0	71
						Arsenic	10	10	0.026	0.002	70	0
						Iron	1,000	1,000	2.650	0.162	82	0
King Creek (MT40I001_040)	L-5	0.02	0.002	364	397	Cadmium	0.70	0.75	0.0001	0.00001	79	83
				NA		Arsenic	10	10	0.0011	0.0001	30	24
						Selenium	5	5	0.0005	0.00005	88	89
Lodge Pole Creek (MT40I001_050)	Z-7	4.58	0.35	149	200	Cadmium	0.36	0.45	0.009	0.001	50	60
				NA		Mercury	0.05	0.05	0.001	0.0001	90	90
Mill Gulch (MT40E002_100)	L-7	0.056	0.015	387	391	Copper	29.65	29.91	0.009	0.002	98	96
				NA		Mercury	0.05	0.05	0.00002	0.000004	90	90
						Selenium	5	5	0.002	0.0004	96	82
Montana Gulch (MT40E002_010)	L-2	1.14	0.44	383	397	Cadmium	0.73	0.75	0.004	0.002	88	93
						Nickel	162.46	167.47	1.0	0.40	0	35
						Zinc	373.82	385.36	2.30	0.92	0	64
				NA		Arsenic	10	10	0.062	0.024	59	68
						Cyanide	5.2	5.2	0.032	0.012	0	82
						Selenium	5	5	0.031	0.012	88	82

Table 5-22. Example metals TMDLs for waterbodies in the Landusky TPA

Stream Segment (Segment ID)	Station	Discharge (cfs) High flow	Discharge (cfs) Low flow	Hardness High flow	Hardness Low flow	Metal	Target Concentration (µg/L) High flow	Target Concentration (µg/L) Low flow	TMDL (lbs/day) High flow	TMDL (lbs/day) Low flow	Percent Load Reduction Based on Sampled Target Exceedance High flow	Percent Load Reduction Based on Sampled Target Exceedance Low flow
Rock Creek (MT40E002_090)	L-23	0.446	0.021	142	283	Cadmium	0.35	0.58	0.0008	0.00007	85	80
						Copper	12.59	22.69	0.030	0.0026	80	0
						Lead	4.97	11.96	0.012	0.0014	85	10
						Zinc	161.27	289.28	0.388	0.033	66	0
				NA		Mercury	0.05	0.05	0.0001	0.000006	90	90
						Selenium	5	5	0.012	0.0006	0	45
Ruby Creek (MT40E002_060)	Z-32	0.37	0.03	400	369	Cadmium	0.76	0.71	0.0015	0.0001	99	98
						Copper	30.5	28.47	0.061	0.005	99	98
						Lead	18.58	16.77	0.037	0.003	93	96
						Zinc	387.83	362.21	0.77	0.059	96	90
				NA		Aluminum	87	87	0.174	0.014	13	0
						Mercury	0.05	0.05	0.0001	0.00001	99	95
						Selenium	5	5	0.01	0.0008	0	80
Ruby Gulch (MT40E002_070)	Z-15	0.40	0.12	387	393	Cadmium	0.74	0.75	0.0016	0.0005	94	96
						Chromium	261.06	264.37	0.564	0.171	0	0
				NA		Aluminum	87	87	0.19	0.056	55	99
						Cyanide	5.2	5.2	0.011	0.003	85	45
						Mercury	0.05	0.05	0.0001	0.00003	98	90
						Selenium	5	5	0.011	0.003	50	50
Sullivan Gulch (MT40E002_110)	D-4	0.083	0.007	191	269	Cadmium	0.44	0.56	0.0002	0.00002	94	50
						Lead	7.25	11.21	0.003	0.0004	85	90
						Zinc	207.32	277.11	0.093	0.010	73	5
				NA		Iron	1,000	1,000	0.45	0.038	1	48
						Selenium	5	5	0.00019	0.0002	55	0

Table 5-22. Example metals TMDLs for waterbodies in the Landusky TPA

Stream Segment (Segment ID)	Station	Discharge (cfs)		Hardness		Metal	Target Concentration (µg/L)		TMDL (lbs/day)		Percent Load Reduction Based on Sampled Target Exceedance	
		High flow	Low flow	High flow	Low flow		High flow	Low flow	High flow	Low flow	High flow	Low flow
Swift Gulch Creek (MT40I002_010)	L-19	0.43	0.065	242	347	Cadmium	0.56	0.68	0.0013	0.0002	97	92
						Copper	21.73	27.01	0.050	0.009	87	0
						Lead	11.21	15.51	0.0260	0.0054	96	45
						Nickel	120.49	149.45	0.279	0.052	30	73
						Zinc	277.11	343.83	0.643	0.121	80	95
				NA		Aluminum	87	87	0.202	0.031	86	87
						Arsenic	10	10	0.023	0.0035	77	88
						Cyanide	5.2	5.2	0.012	0.002	0	94
						Iron	1,000	1,000	2.32	0.351	97	99
						Tl	0.24	0.24	0.0006	0.0001	84	84

5.7 Loading Summaries and Allocations

The following sections provide a loading summary and source allocation is for each pollutant-waterbody combination with a TMDL. Loading summaries are based on the sample data contained in **Appendix B** and summarized in **Appendix F**. The aim of the loading summaries is to illustrate loading trends and discuss seasonal and significant loading sources and pathways.

As discussed in **Section 4.0**, a TMDL is the sum of all of the load allocations (LAs), wasteload allocations (WLAs), and a margin of safety (MOS). LAs are allowable pollutant loads assigned to nonpoint sources and may include the cumulative pollutant load from naturally occurring and human caused sources. When possible, LAs are provided separately to naturally occurring sources. WLAs are allowable pollutant loads that are assigned to permitted and non-permitted point sources. Mining related waste sources such as treatment plant discharges, leach pads, and waste rock repositories are non-permitted point sources subject to WLAs. TMDLs are expressed by the following general equation:

$$\mathbf{TMDL = LA_{NB} + WLA_{MS} + MOS}$$

The prevailing human-caused source of metals loading in the Landusky TPA is from ZMI mining at the Zortman and Landusky mines between 1979 and 1998. Where adequate data are available to evaluate loading from individual mining sources, these non-permitted point sources will be given separate WLAs. Where data from discrete mining sources is not available, loading contributions from mining are grouped into composite WLAs. The adaptive management process discussed in **Section 5.9** is recommended where more detail is needed for future refinement and adjustment of composite WLAs to mining sources.

TMDLs are required to incorporate a MOS. All metals and cyanide TMDLs in this document apply an implicit MOS through the adoption of a variety of conservative assumptions in calculating TMDLs and estimating pollutant loads. These assumptions are described in more detail in **Section 5.8.2.** Therefore, the implicit MOS is implied in the TMDL equations developed below and not repeated in each developed equation.

5.7.1 Alder Gulch (MT40E002_051)

Loading Summary

Metals target exceedances in Alder Gulch result from mine related ARD entering its northern tributaries of Carter Gulch and Alder Spur from Zortman Mine facilities. These include seepage from beneath the Alabama Pit complex, seepage through 3.7 million tons of waste rock in the Alder Waste Rock Repository, and seepage from beneath three leach pads used between 1979 and 1984 that occupy the ridge separating Alder and Ruby gulches (**Figure A-16**).

The bulk of water quality data for Alder Gulch dates from 1990 to 1998. Elevated concentrations of Cd, Cu, Pb, Se, and Zn in Alder Gulch coincide with completion of the Alder Waste Rock Repository in 1990. Large spikes in metals concentrations occur during low flows from 1990-1992. The metals listings for Alder Gulch largely result from data collected during this period. The ARD conditions causing elevated metals concentrations also affect water column SO_4 concentration. **Figure 5-7** shows the SO4 monitoring record for site Z-8 in Alder Gulch and the corresponding concentration spike from 1990 to 1992.

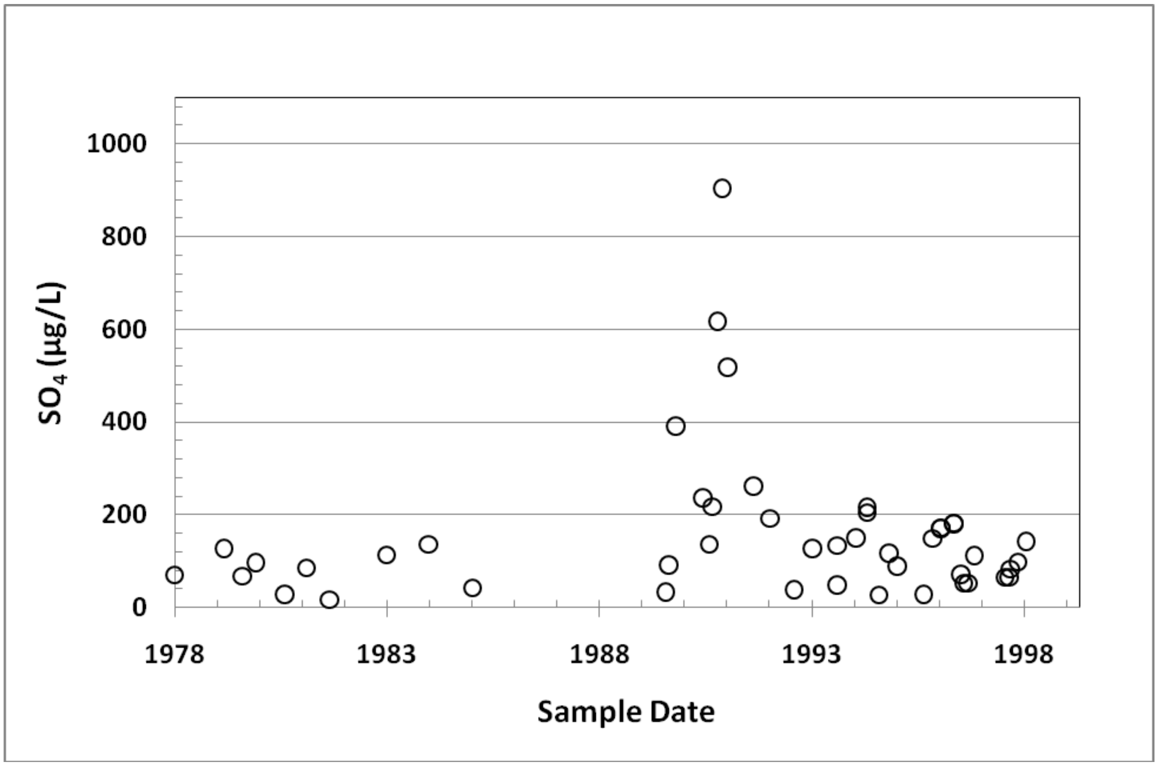

Figure 5-7. Sulfate concentration record at site Z-8 in Alder Gulch.

Surface reclamation of the Alder Waste Rock Repository was complete in 1992. Seepage capture systems were installed during 1994 in Carter Gulch below the Alder Waste Rock Repository and in Alder Spur below the 83 and 84 leach pad dikes. A decrease in surface water metals concentrations occurred after reclamation and continued until monitoring ended in 1998.

An extended period of heavy rainfall during May of 2011 caused a slope failure at the base of the Alder Gulch Waste Rock Repository. The failure removed the Carter Gulch seepage capture system. The data used to develop Alder Gulch TMDLs and allocations does not include that collected after the storm damage. Future monitoring of Gulch water quality will require lower MDLs s that allows a comparison of results to aquatic life criteria.

TMDLs and Allocations

The metals TMDLs and allocations for high and low flow conditions in Alder Gulch are summarized below and **Table 5-23**. The allocations for Cd, Pb, Se, and Zn include load allocations to natural background concentrations (**$LA_{ALDR\ GUL\ NB}$**) and a wasteload allocation to mining sources of these four metals (**$WLA_{ALDR\ GUL\ MS}$**). Natural background loading is calculated using the median metal concentrations of Cd, Pb, Se, and Zn from the four Alder Gulch background sites Z-60, Z-61, Z-62, and AGSS-10 located in headwaters tributaries. The Alder Gulch TMDL is summarized by the following equation:

$$\mathbf{TMDL_{ALDR\ GUL} = LA_{ALDR\ GUL\ NB} + WLA_{ALDR\ GUL\ MS}}$$

Where background sample analysis results are less than MDLs, one half of the MDL is the assumed background concentration. The wasteload allocation to mining sources is obtained by subtracting the calculated background load from the TMDL. The allocation scheme for Cd, Pb, Se, and Zn assumes that natural background loading rates do not exceed water quality standards. The allocations also assume that further application of BMPs to mining sources will reduce loading so that TMDLs and water quality standards are met.

A separate allocation scheme is proposed for Cu and Hg TMDLs. A composite WLA allocation to the sum of natural background and mining sources is proposed for Cu and Hg and is reflected in the following equation

$$\mathbf{TMDL_{ALDR\ GUL} = (WLA_{\ (ALDR\ GUL\ NB\ +\ ALDER\ GUL\ MS)})}$$

Using a composite allocation, the sum of allowable Cu loading from natural background, plus mining sources, is equal to the TMDLs of 0.010 lbs/day under high flow and 0.006 lbs/day under low flow conditions. The TMDL equations for Cu are inserted into **Table 5-23** for high and low flow conditions.

Copper concentrations measured at the four background sites from 1996 to 1998 exceeded the hardness-based CAL criteria by a factor of three. All samples were collected under high flow conditions. During the same period, a similar high flow exceedance magnitude was measured at site Z-2, the site farthest upstream among the three current condition sites in Alder Gulch. The composite allocation serves as a limit on Cu loading until targeted monitoring in headwaters reaches of Alder Gulch can better describe natural background Cu loading under a range of flow conditions. The composite WLA to background plus mining sources assumes that background Cu concentrations are actually less than the aquatic life target criteria and that applied BMPs can further reduce Cu loading from mining sources.

A composite allocation similar to that for Cu is proposed for Hg in Alder Gulch. Natural background Hg loading to Alder Gulch is obscured by the use of MDLs that exceed the HH criterion of 0.05 µg/L. Of the 52 Hg results for Alder Gulch, 51 are reported as less than the MDL. The composite allocation to natural background and mining sources of Hg will equal 0.00041 lbs/day under high flow and 0.000014 lbs/day under low flow conditions. The TMDL equations for high and low flow Hg loading are inserted into **Table 5-23**. Additional monitoring at background and current condition sites, with sufficiently low MDLs applied during both high and low flow conditions is required to better refine the Hg allocation.

Table 5-23. Cadmium, copper, lead, mercury, selenium and zinc TMDLs and load- and wasteload allocation examples for Alder Gulch at site Z-8.

Metal	Flow Conditions	TMDL (lbs/day)	Percent Reduction Needed	LA_{NB} (lbs/day)	WLA_{MS} (lbs/day)
Cadmium	High flow	0.003	97	0.0008	0.0022
	Low flow	0.0002	99	0.00003	0.00017
Copper	High flow	0.10	91	**TMDL = ($LA_{ALDR\ GUL\ NB}$+$WLA_{ALDR\ GUL\ MS}$) = 0.10 lbs/day**	
	Low flow	0.006	96	**TMDL ($LA_{ALDR\ GUL\ NB}$+$WLA_{ALDR\ GUL\ MS}$) = 0.006 lbs/day**	
Lead	High flow	0.04	93	0.012	0.028
	Low flow	0.003	7	0.0004	0.0026
Mercury	High flow	0.00041	90	**TMDL = ($LA_{ALDR\ GUL\ NB}$+$WLA_{ALDR\ GUL\ MS}$) = 0.00041 lbs/day**	
	Low flow	0.000014	90	**TMDL = ($LA_{ALDR\ GUL\ NB}$+$WLA_{ALDR\ GUL\ MS}$) = 0.000014 lbs/day**	

Table 5-23. Cadmium, copper, lead, mercury, selenium and zinc TMDLs and load- and wasteload allocation examples for Alder Gulch at site Z-8.

Metal	Flow Conditions	TMDL (lbs/day)	Percent Reduction Needed	LA_{NB} (lbs/day)	WLA_{MS} (lbs/day)
Selenium	High flow	0.041	97	0.0041	0.037
	Low flow	0.00135	0	0.000135	0.00121
Zinc	High flow	1.29	50	0.162	1.128
	Low flow	0.082	80	0.0054	0.0766

5.7.2 Beaver Creek, (MT40M001_011)

Loading Summary

Only high flow target exceedances for lead occurred in Beaver Creek at sites Z-31 and Z-39. High flow exceedances also occurred at background site Z-27. Despite its remoteness from obvious sources, exceedances at site Z-27 are similar in magnitude to those farther downstream at sites with more conceivable sources from road sediment and mine tailings at the Beaver Mine near site Z-39. A high flow sample collected in 2005 about 1.5 miles below site Z-39 from DEQ assessment site M31BEVRC03 contained less than 0.5 µg/L. The sediment sample collected at site M31BEVRC03 did not exceed the sediment lead target of 91.3 µg/g.

The exceedances occurred in samples collected from 1990 to 2001 and were about 10 times the CAL criteria. The data suggest a similar level of loading at both the background site and at the upper two current conditions sites prior to 2001. The similar exceedance pattern for both the background and current condition sites suggests either naturally high background lead loading at high flows with little downstream effects or some level of human-caused loading affecting site Z-27 in a headwaters tributary.

TMDLs and Allocations

The similarity among the upper three sites in number, degree, and timing of exceedances prevents a specific load allocation to background sources of lead in Beaver Creek. Therefore, a composite allocation is proposed to the sum of natural background ($LA_{BVR\ CR\ NB}$) and Beaver Creek mining sources ($WLA_{BVR\ CR\ MS}$) during high flow conditions. The composite load/wasteload allocation is calculated based on Beaver Creek flow at site Z-31 and is calculated by making the sum of the composite allocation equal to the TMDL as summarized in the following equation:

$$\mathbf{TMDL = (LA_{BVR\ CR\ NB} + WLA_{BVR\ CR\ MS}) = 0.0057\ lbs/day.}$$

In this case, the sum of natural background and mining sources is equal to the high flow TMDL of 0.0057 pounds of lead per day.

5.7.3 South Big Horn Creek, (MT40I001_030)

Loading Summary

Loading sources to South Big Horn Creek include natural background sources and mining sources in Swift Gulch Creek affecting South Big Horn Creek water quality below the Swift Gulch Creek confluence. Swift Gulch Creek water quality is affected below a series of streambank springs hydrologically connected to the August-Surprise-Queen Rose pit complex at the Landusky Mine. The location of the metal contaminated springs is approximately one half mile above the Swift Gulch Creek confluence with South Big Horn Creek. The oxidation of iron sulfides in the bottom of the pit complex creates acidic groundwater within a bedrock shear zone that serves as a flow conduit between the pits and surface water in Swift Gulch Creek.

Water quality data collection for most metals in South Big Horn Creek at site L-48 began in the spring of 1997 and continued through the following year. Sampling was resumed in 2003 and has continued to the present on a seasonal basis. Monitoring a site L-48A began in 2003 has continued to the present on a near monthly basis.

Deteriorating water quality in Swift Gulch Creek prompted construction of a seasonally operated lime addition treatment plant in the Swift Gulch Creek drainage below the contaminated springs in 2010. The plant receives wastewater from two upstream capture systems and treated water is discharged to two settling ponds downstream of the plant. The treated effluent returns to the Swift Gulch Creek channel below the ponds. Extremely high flows in Swift Gulch Creek during May of 2011 severely damaged the capture systems causing a shutdown of the treatment plant pending repairs to the capture system plumbing.

TMDLs and Allocations

Example metals TMDLs and allocations for high and low flow conditions in South Big Horn Creek at site L-48 are summarized below in **Table 5-24**. The allocations consist of load allocations to natural background sources ($LA_{SBH\ CR\ NB}$) of the six metal parameters in the table and wasteload allocations to mining sources ($WLA_{SBH\ CR\ MS}$) at the Landusky Mine. The TMDL is stated in the following equation:

$$\mathbf{TMDL_{SBH\ CR} = LA_{SBH\ CR\ NB} + WLA_{SBH\ CR\ MS}}$$

Natural background loading is represented by median high and low flow metal concentrations of Al, As, Cd, Fe, Ni, and Zn calculated for site L-21, located just upstream of the confluence with Swift Gulch Creek. The WLAs for South Big Horn Creek include those developed below in **Table 5-35** for Swift Gulch Creek for the metal pollutants below in **Table 5-24**. The WLAs in the two tables do not sum to the South Big Horn Creek TMDLs for these metal because the WLAs for the two stream segments are based on sample collected on different dates with different flow and hardness conditions.

Table 5-24. Metals TMDLs and allocation examples for South Big Horn Creek at site L-48

Metal	Flow Conditions	TMDL (lbs/day)	Percent Reduction Needed	LA_{NB} (lbs/day)	WLA_{MS} (lbs/day)
Aluminum	High flow	0.230	0	0.132	0.098
	Low flow	0.014	71	0.008	0.006
Arsenic	High flow	0.026	70	0.004	0.022
	Low flow	0.002	0	0.0002	0.0018
Cadmium	High flow	0.001	92	0.00026	0.00074
	Low flow	0.0001	90	0.00001	0.00009
Iron	High flow	2.650	82	0.340	2.31
	Low flow	0.162	0	0.002	0.160
Nickel	High flow	0.280	65	0.0265	0.254
	Low flow	0.027	60	0.00012	0.0269
Zinc	High flow	0.635	65	0.013	0.622
	Low flow	0.063	90	0.0008	0.0622

Cadmium, Ni, and Zn exceedances are common under both high and low flow conditions. Iron and As exceedances are almost exclusively high flow phenomena and low flow reductions are not required. Data for dissolved Al are sparse and restricted to low flow conditions. Therefore, reductions to high flow Al are not specified. The allocations assume that applying BMPs to mining sources will meet the TMDLs and water quality standards.

5.7.4 King Creek (MT40I001_040)

Loading Summary

King Creek sources of As, Cd, and Se are residual tailings from historic cyanide mills near the top of the drainage and oxide waste rock from the nearby August-Little Ben and Gold Bug pits. The tailings were largely removed during restoration in 2000. Waste rock surfaces received coversoil and were revegetated. Stormwater and seepage through the waste rock collects behind a downstream interception trench, is routed through a passive treatment system for nutrient removal and surfaces as a seep at site L-5. The upper extent of the drainage is truncated by the August-Surprise-Queen Rose pit complex at the Landusky Mine. A broad groundwater divide exists beneath the pit complex and local ARD-affected groundwater may be a periodic source of metals in King Creek. Water quality data are available for sites L-5 in the upper drainage, the inlet to the Cumberland retention pond (site 503), and monitoring site L-39 located about one half mile downstream.

TMDLs and Allocations

The extent of mining disturbance in King Creek prevents locating a background water quality site within the drainage. Site L-40, located in a headwaters tributary of Montana Gulch is similar to upper King Creek in that both drain undisturbed portions of Mission Peak. The water quality record from site L-40 is used here to develop an allocation to natural background sources of metals loading.

Mining sources in upper King Creek receive a wasteload allocation ($\mathbf{WLA_{KG\ CR\ MS}}$). A load allocation to naturally background sources ($\mathbf{LA_{KG\ CR\ NB}}$) is calculated based on flow at L-5 and metals concentrations from site L-40 in a headwater tributary of Montana Gulch that is assumed to represent the background condition. Where metals concentrations at L-40 are less than MDLs, one half of the MDLs is used as the concentration value. The $\mathbf{WLA_{KG\ CR\ MS}}$ is calculated by subtracting the $\mathbf{LA_{KG\ CR\ NB}}$ from the TMDL. The King Creek TMDL is stated in the following equation:

$$\mathbf{TMDL_{KG\ CR} = LA_{KG\ CR\ NB} + WLA_{KG\ CR\ MS}}$$

The TMDL components are summarized below and **Table 5-25** shows example TMDLs and allocations for measured high and low flow conditions in King Creek at site L-5.

Table 5-25. Metals TMDLs and allocation examples for arsenic, cadmium, and selenium in King Creek at site L-5.

TMDLs				**Allocations**	
Metal	**Flow Condition**	**TMDL (lbs/day)**	**Needed Percent Reduction**	**$LA_{KG\ CR\ NB}$ (lbs/day)**	**$WLA_{KG\ CR\ MS}$ (lbs/day)**
Arsenic	High flow	0.0011	30	0.0003	0.0008
	Low flow	0.0001	24	0.00003	0.00007
Cadmium	High flow	0.0001	79	0.00004	0.00006
	Low flow	0.00001	83	0.000004	0.000006
Selenium	High flow	0.0005	88	0.0003	0.0002
	Low flow	0.00005	89	0.00003	0.00002

This allocation scheme assumes that natural loading rates do not cause water quality standards to be exceeded and applying BMPs to mining sources will result in the loading reductions necessary to meet the TMDLs and water quality standards.

5.7.5 Lodge Pole Creek (MT40I001_050)

Loading Summary

Potential mining sources of Cd are associated with the Ross Pit area that is the northern-most extent of the Zortman Mine (**Figure A-16**). Although Hg has not been detected in Lodge Pole Creek at sites Z-2 and Z-29 upstream of the Fort Belknap Reservation boundary, historic placer mining within the planning area, using mercury amalgamation for gold separation, could be a potential source of the positive Hg detection at USGS station 06154430 near the town of Lodge Pole. This detection was extrapolated to the segment of Lodge Pole Creek south of the reservation boundary. There were two positive Hg detections among 24 Hg results for background sites Z-28 and Z-30, both occurred on the same date (5/15/91) under high flow conditions. Mercury has not been detected in 22 subsequent samples from these sites through 1996.

TMDLs and Allocations

Example The TMDLs and allocations for Cd and Hg in Lodge Pole Creek at site Z-7are summarized in **Table 5-26**. The load allocation to natural background sources of Cd (**$LA_{LP\ CR\ NB}$**) is calculated by multiplying high and low discharge values by the average metal concentrations at sites Z-28 and Z-30. Where results at these sites are less than MDLs, one half of the MDL is used as the concentration value in the calculations. The wasteload allocations to mining sources (**$WLA_{LP\ CR\ MS}$**) of Cd are calculated by subtracting the **$LA_{LP\ CR\ NB}$** from the Cd TMDLs. The TMDL is stated in the following equation:

$$\mathbf{TMDL_{LP\ CR} = LA_{LP\ CR\ NB} + WLA_{LP\ CR\ MS}}$$

The allocations for Hg in Lodge Pole Creek are formulated as a composite wasteload allocation to natural background plus mining sources(**$WLA_{(LP\ CR\ NB\ +\ LP\ CR\ MS)}$**) that is set equal to the high and low flow Hg TMDLs. The Lodge Pole Creek Hg TMDL is stated in the following equation that is inserted into **Table 5-26**.:

$$\mathbf{TMDL_{LP\ CR} = WLA_{(LP\ CR\ NB\ +\ LP\ CR\ MS)}}$$

This approach is used because the MDLs for Hg used in monitoring are as much as an order of magnitude higher than the most restrictive water quality criteria. The high MDLs, combined with the large number of non-detections in both the natural background and current condition datasets equate to equal reduction requirements (90%) for the two datasets in order to meet the HH criterion of 0.05 µg/L. In other words, the high MDLs and large number of non-detections do not allow a clear, separate definition of the natural background and mining contributions to the TMDLs.

The composite allocation scheme assumes that natural background concentrations are less than the HH criterion and that actual Hg loading from mining sources both exceeds this criterion and can be reduced by further application of BMPs to mining sources. Further monitoring of both background and current condition sites using appropriate MDLs will be needed to fine tune the composite allocation and more accurately define loading from both source categories.

Table 5-26. Metals TMDLs and allocation examples for cadmium and mercury in Lodge Pole Creek at site Z-7

TMDLs				**Allocations**	
Metal	**Flow Condition**	**TMDL (lbs/day)**	**Needed Percent Reduction**	**LA_{NB} (lbs/day)**	**WLA_{MS} (lbs/day)**
Cadmium	High flow	0.009	50	0.00124	0.0078
	Low flow	0.001	60	0.000095	0.00091
Mercury	High flow	0.001	90	$\mathbf{TMDL_{LP\ CR} = WLA_{(LP\ CR\ NB\ +LP\ CR\ MS)}}$ = 0.001 lbs/day	
	Low flow	0.0001	90	$\mathbf{TMDL_{LP\ CR} = WLA_{(LP\ CR\ NB\ +LP\ CR\ MS)}}$ = 0.0001 lbs/day	

5.7.6 Mill Gulch (MT40E002_100)

Loading Summary

Metals loading to Mill Gulch is from a combination of surface stormwater and subsurface drainage from the 1987 leach pad, its supporting dike, and the Mill Gulch Waste Rock Dump occupying the upper reach of the drainage. Subsurface seepage from the more distant Gold Bug pit complex is also a potential source of ARD affected groundwater discharging to Mill Gulch surface water. The Gold Bug pit was used as a repository for waste rock removed from the sulfidic August-Little Ben/Queen Rose pit complex. The Mill Gulch capture system was installed at the toe of the Mill Gulch Waste Rock Dump in 1997. Water is piped from the capture system to the Landusky wastewater treatment plant.

The metal exceedances resulting in the impairment listings for Cu and Se are concentrated at sites 506 and L-36, both located below the capture pond constructed near the base of the waste rock dump that occupies the upper portion of the drainage. Site 506 is a stormwater monitoring site below the pond and L-36 is the bypass of the seepage capture system.

TMDLs and Allocations

The potential metals sources are mining sources that receive a wasteload allocation ($\mathbf{WLA_{MIL\ GUL\ MS}}$). The $\mathbf{WLA_{MIL\ GUL\ MS}}$ is calculated by subtracting the load allocation to natural background sources ($\mathbf{LA_{MIL\ GUL\ NB}}$) from the TMDL. The allocations for allowable Cu and Se loading are stated in the following equation:

$$\mathbf{TMDL = LA_{MIL\ GUL\ NB} + WLA_{MIL\ GUL\ MS}}$$

The **$LA_{MIL\ GUL\ NB}$** is calculated using the mean concentrations from sites L-40 and RCSS-5. Where background Cu and Se concentrations at sites L-40 and RCSS-5 are less than the MDLs, one half the detection limit is used to calculate the LA. Use of one half the detection limit incorporates an implicit MOS by increasing the needed reduction above what would be calculated using the MDL.

The Hg dataset for Mill Gulch contains only results reporting less than detectable levels. The MDLs (1, 0.2, and 0.6 µg/L), all exceed the 0.05 µg/L HH criterion for Hg. Therefore, separate loading contributions from natural background and mining sources of Hg cannot be determined from the available monitoring results.

A Hg TMDL is developed to address the previous a Hg listing and Hg allocations are to a composite WLA to natural background and mining sources (**$WLA_{(MIL\ GUL\ NB\ +\ MIL\ GUL\ MS)}$**). This TMDL is reflected in the following equation:

$$\mathbf{TMDLMIL\ GUL = WLA_{MIL\ GUL\ NB\ +\ MIL\ GUL\ MS}}$$

Additional monitoring using adequate MDLs is needed to verify the Hg listing, source contributions, and reductions if needed.

Table 5-27 shows example Cu, Hg, and Se TMDLs and allocations for measured high and low flow conditions at site L-7 in Mill Gulch. Because of the loading uncertainty resulting from high MDLs, the Hg allocation is a composite of s in At this time

Table 5-27. Copper, Hg, and Se TMDLs and load allocation examples for Mill Gulch at L-7

Metal	Flow Conditions	TMDL (lbs/day)	Percent Reduction Needed	LA_{NB} (lbs/day)	WLA_{MS} (lbs/day)
Copper	High flow	0.009	98	0.0015	0.0075
	Low flow	0.002	96	0.0004	0.0016
Mercury	High flow	0.000015	90	**$TMDL_{MIL\ GUL}$ = 0.000015 = $WLA_{MIL\ GUL\ NB\ +\ MIL\ GUL\ MS}$**	
	Low flow	0.000004	90	**$TMDL_{MIL\ GUL}$** = 0.000004 = **$WLA_{MIL\ GUL\ NB\ +\ MIL\ GUL\ MS}$**	
Selenium	High flow	0.002	96	0.0008	0.0012
	Low flow	0.0004	82	0.0002	0.0002

This allocation scheme assumes that background loading rates do not cause water quality standards to be exceeded and applying BMPs to the mining sources will result in the loading reductions necessary to meet the TMDLs and water quality standards.

5.7.7 Montana Gulch (MT40E002_010)

Loading Summary

Montana Gulch drains the western third of the Landusky Mine (see **Figure A-17**). Its headwaters consist of three tributaries. The western branch drains an undisturbed watershed to the south and west of Mission Peak. Site L-40, selected as representing natural background water quality, is near the base of this tributary. The middle tributary begins at the south end of the August-Little Ben mine pit and its upper reach contains the Montana Gulch Waste Rock Dump. At the base of the waste rock valley fill is the upper Montana Gulch seepage capture system. It intercepts seepage through the waste rock valley fill and the discharge from a buried portal to the former August Mine. The capture system flow is piped to the Landusky wastewater treatment plant. The upper reach of the eastern headwaters branch drains the reclaimed surface near the Gold Bug and South Gold Bug mine pits and contains the 84 leach pad and dike farther downstream. The area where the three branches converge once contained the 85/86 leach pad until its removal from 2002 to 2005. The ridge separating Montana Gulch from Mill Gulch is occupied by the 79, 80-82, and 83 leach pads. Below the headwaters confluence, Montana Gulch contains a wastewater retention pond.

The Montana Gulch pond receives the discharge from the Landusky wastewater treatment plant (Landusky WWTP) that operates around the clock at an average annual discharge of 225.4 million gallons (0.96 cfs). The pond discharges at a rate of about 1.3 cfs to Montana Gulch Spectrum Engineering 2006). Thus, the average daily flow from surface flow and seepage sources above pond, that are not routed to the Landusky WWTP, is about 0.34 cfs or 153 gallons per minute. Below the pond, Montana Gulch flows south for about a mile to its confluence with Rock Creek.

Montana Gulch is listed for As, Cd, Cu, and pH in the 2010 Integrated Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010). The water quality data indicate that As and Cu are not currently impairing aquatic life uses and additional listings are warranted for cyanide, Ni, Se, and Zn. Among the four monitoring sites selected to represent current conditions (L-16, L-47, L-2, 591), the Montana Gulch pond overflow discharge (site 591) accounts for 97 percent of the records for the most recent 10 years. **Figure 5-8** is a graph of the sulfate concentration at site 591 in Montana Gulch during the past 10 years. The general water quality trend of the retention pond discharge is toward increasing effects of ARD at the Landusky Mine. The graph reflects a trend of increasing acidity generated by sulfide oxidation in the sources of wastewater that are routed to the pond from the Landusky WWTP.

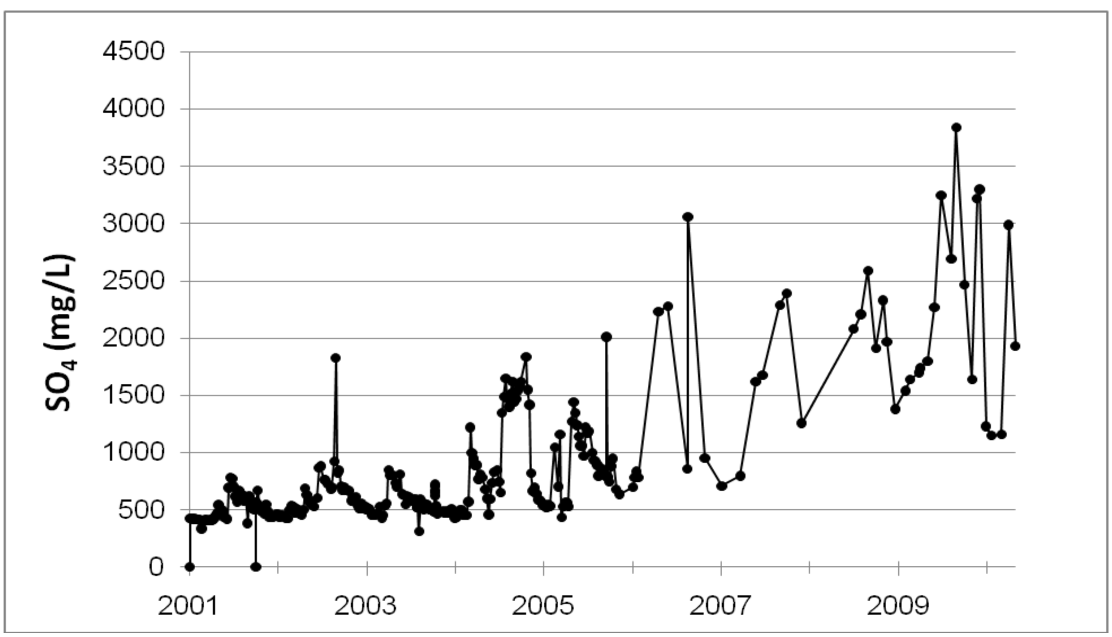

Figure 5-8. Graph of the sulfate concentration in the Montana Gulch pond discharge during the past 10 years.

The increasing trend in **Figure 5-8** for sulfate is similar to those for Cd, CN, Ni, Se and Zn. Although the datasets for the three current condition sites downstream of site 591 are much smaller, they exhibit a similar trend of deteriorating water quality. **Figure 5-9** shows the sulfate data points for sites L-16, L-47 and L-2 from 2001 through 2009.

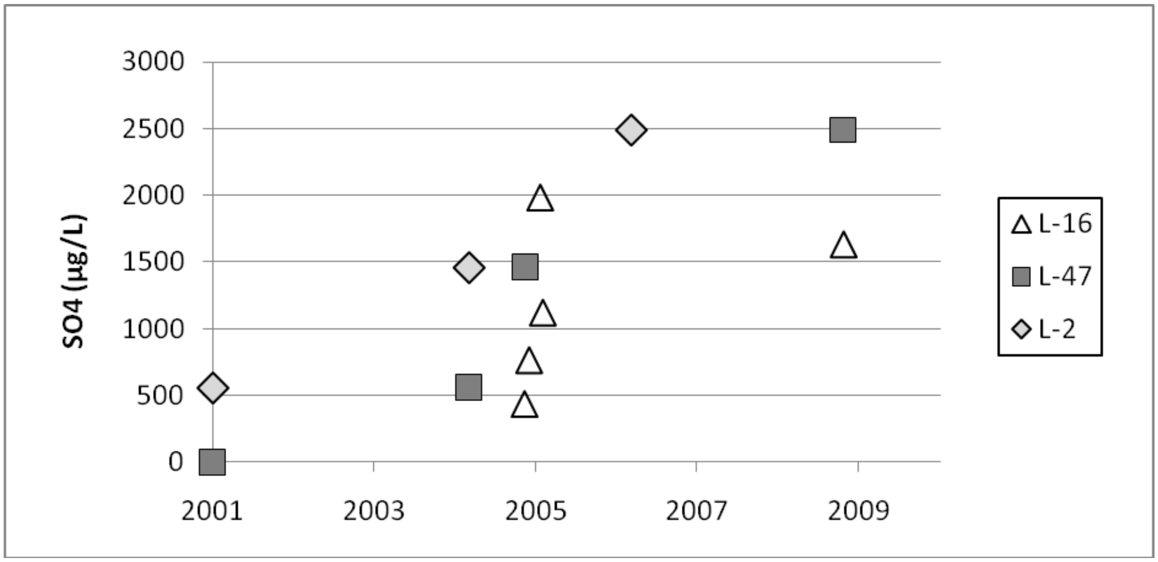

Figure 5-9. Graphs of surface water sulfate concentration at sites L-16, L-47, and L-2 during the past 10 years

Among the current metals pollutant causes for Montana Gulch, As has been on a decreasing trend since 2001. Although the As record contains numerous human health exceedances, the classification of Montana Gulch as a C-3 stream with naturally marginal drinking water support, shifts the focus of target comparisons to the CAL and AAL criteria. Arsenic concentrations have generally been an order of magnitude less than the CAL and AAL targets. **Figure 5-10** shows the trend in As concentration at site 591 over the past decade.

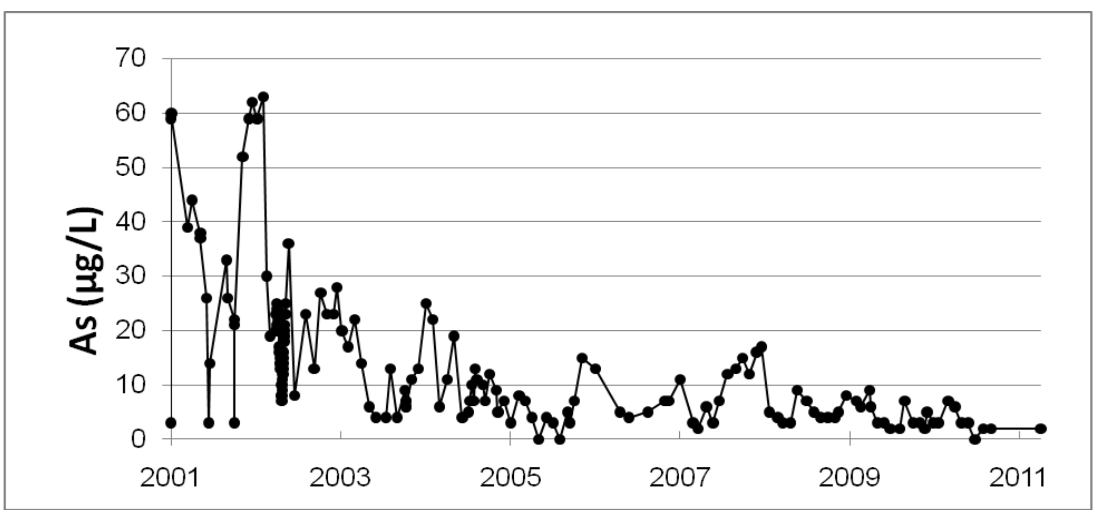

Figure 5-10. Graph of the As concentration in the Montana Gulch pond discharge during the past 10 years.

Although, Cu concentrations in Montana Gulch are increasing slightly, (**Figure 5-11**) the CAL and AAL exceedance rates over all flow conditions are about one percent. No TMDLs or allocations are proposed for Cu in Montana Gulch.

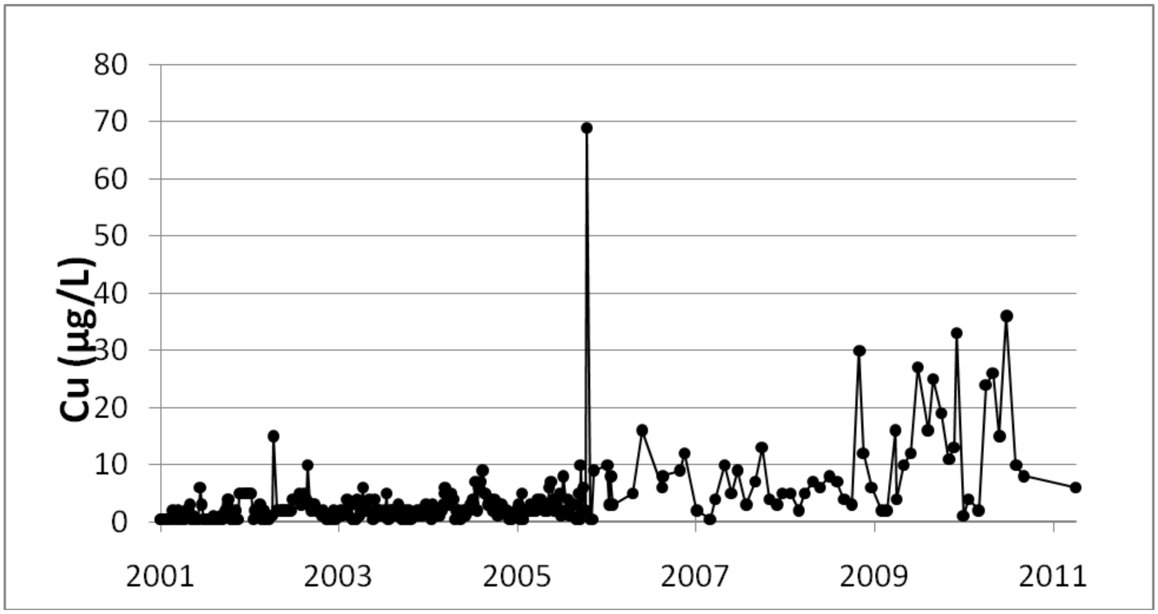

Figure 5-11. Graph of Cu concentration in the Montana Gulch pond discharge during the past 10 years.

TMDLs and Allocations

The flow in Montana Gulch can be divided into two broad categories:

1. Surface and groundwater that is intercepted , treated, and discharged from the Landusky WWTP, and
2. Surface and groundwater that enter Montana Gulch from sources other than the Landusky WWTP.

The second category comprises waters that have been affected by mining activity and waters of natural background quality. Waters entering Montana Gulch from the watershed upstream of site L-40 are assumed to be of natural background quality because the drainage has not been mined. This is also the case in two downstream tributaries that enter Montana Gulch from the west. Tributaries entering Montana Gulch from the east are likely to be affected by the Landusky Mine. Some of the mine-affected water is intercepted and treated prior to its discharge to Montana Gulch. It is unlikely that all drainage to Montana Gulch from the Landusky mine enters a capture system and receives treatment. Therefore, category 2 above is necessarily a mixture of naturally occurring waters and untreated wasters affected by the Landusky Mine. The metals loading allocations for Montana Gulch include a WLA to the Landusky WWTP (**WLA_{LWWTP}**) and a second WLA to a composite of natural background sources (**NB**) from both mined and un-mined areas of the watershed and untreated mining sources (**UTMS**) from mined areas. The TMDL allocations are expressed by the following equation:

$$\mathbf{TMDL = WLA_{LWWTP} + WLA_{(MT\ GUL\ NB\ +\ MT\ GUL\ UTMS)}}$$

Until additional water quality and streamflow monitoring can better define the actual proportion of each WLA to the TMDL, the proportions at site L-2 near the mouth of Montana Gulch are assumed equal to the proportions of these sources entering the Montana Gulch retention pond. Long-term monitoring of the pond discharge to Montana Gulch and the discharge entering the pond from the Landusky WWTP indicates that 74 percent (430 gmp) of the 580 gpm pond discharge is from the treatment plant. The remaining 26 percent of the pond discharge (150 gpm) is from combined natural background and untreated mining sources.

Table 5-28. Metals and cyanide TMDLs and allocation examples for Montana Gulch at site L-2

Metal	Flow Conditions	TMDL (lbs/day)	Percent Reduction Needed	WLA_{LWWYP} (lbs/day)	$WLA_{(NB + UTMS)}$ (lbs/day)
Cadmium	High flow	0.004	88	0.003	0.001
	Low flow	0.002	93	0.0015	0.0005
Cyanide	High flow	0.032	0	0.024	0.008
	Low flow	0.012	82	0.009	0.003
Nickel	High flow	1.0	0	0.74	0.26
	Low flow	0.40	35	0.30	0.01
Selenium	High flow	0.031	88	0.023	0.008
	Low flow	0.012	82	0.009	0.003
Zinc	High flow	2.30	0	1.70	0.60
	Low flow	0.92	64	0.68	0.24

The data for CN, Ni, and Zn indicate that reductions are not needed under high flow conditions

5.7.8 Rock Creek (MT40E002_090)

Loading Summary

Rock Creek drains nearly the entire Landusky mine because of its northern Sullivan Gulch, Mill Gulch and Montana Gulch tributaries. Flows in Rock Creek are ephemeral and intermittent above the town of Landusky. Despite its C-3 classification, the Rock Creek water quality record is assessed using HH criteria because of the assumed close connection between surface water and shallow groundwater and the established use of shallow groundwater as a drinking water source for Landusky residents.

The metals loading is from runoff and seepage from waste rock, leach pad, and pad dike sources at the Landusky Mine. Below the confluence with Montana Gulch, Rock Creek loading includes that from the Landusky WWTP. Natural background loading to Rock Creek is represented by the water quality records for sites RCSS-5 in the reach above the Sullivan Gulch confluence and sites Z-60, Z-61, and Z-62 in headwaters tributaries of Alder Gulch to the east.

TMDLs and Allocations

TMDLs and allocations are described for two reaches of Rock Creek: the reach above monitoring site L-23 located below the confluence with Sullivan Gulch, and the reach above monitoring site L-1 that includes loading from Montana Gulch (**Figure F-11**).

Cadmium, Se, and Zn allocations at site 23 include a LA to natural background sources of ($\mathbf{LA_{UPR\ RK\ CR\ NB}}$), and WLA to mining sources of these metals ($\mathbf{WLA_{UPR\ RK\ CR\ MS}}$). The Rock Creek TMDL for Cd, Se, and Zn above site L-23 ($\mathbf{TMDL_{UPR\ ROCK}}$), and allocations are expressed in the following equation:

$$\mathbf{TMDL_{UPR\ ROCK} = LA_{UPR\ RK\ CR\ NB} + WLA_{UPR\ RK\ CR\ MS}}$$

The load allocation for natural background sources of Cd, Se and Zn is calculated from the data from sites RCSS-5, Z-60, Z-61, and Z-62. Where concentrations are less than MDLs, one half the MDL value is used in the calculation. The WLA to mining sources is obtained by subtracting the LA_{NB} from the TMDL. This allocation scheme assumes that natural loading rates do not cause water quality standards to be exceeded and applying BMPs to the mining sources will result in the loading reductions necessary to meet the TMDLs and water quality standards. **Table 5-29** contains example TMDLs and allocations for measured high and low flow conditions in the Rock Creek watershed above site L-23.

Table 5-29. Cadmium, selenium and zinc TMDLs and allocation examples for Rock Creek at site L-23

Metal	Flow Conditions	TMDL (lbs/day)	Percent Reduction Needed	LA_{NB} (lbs/day)	$WLA_{(MS)}$ (lbs/day)
Cadmium	High flow	0.0008	85	0.00005	0.00075
	Low flow	0.00007	80	0.0000057	0.000065
Selenium	High flow	0.012	0	0.002	0.01
	Low flow	0.0006	45	0.000057	0.000543
Zinc	High flow	0.388	66	0.048	0.34
	Low flow	0.033	0	0.002	0.031

A separate allocation scheme is developed for the metals Cu, Hg, and Pb in upper Rock Creek because the data prevent development of separate allocations to natural versus human-caused loading sources. The copper concentrations at sites RCSS-5, Z-60, Z-61, and Z-62 were all obtained during high flows in June of 1996 and May of 1997. All Cu values exceed both the CAL and AAL criteria that apply to flow and hardness conditions on the sample dates. The MDLs reported with the Pb (3 µg/L) and Hg (0.6 µg/L) results for these four sites exceed the CAL criteria. Therefore, the data do not allow development of separate allocations to natural background and human-caused sources of these metals. Until additional Cu, Hg, and Pb data can be collected for a range of flow and hardness conditions, the TMDLs are allocated to a composite WLA that is the sum of natural background and mining sources ($\mathbf{WLA_{UPR\ RK\ CR\ NB\ +\ UPR\ RK\ CR\ MS}}$). The TMDLs and allocation for Cu, Hg, and Pb in Rock Creek at site L-23 can be summarized by the following equation:

$$\mathbf{TMDL = WLA_{UPR'RK\ CR\ NB\ +\ UPR\ RK\ CR\ MS}}$$

Table 5-30 contains example TMDLs and composite allocations for Cu, Hg, and Pb in upper Rock Creek under high and low flow conditions at site L-23. Percent reductions of Pb and Hg are left blank in the table because they could not be calculated for results reporting less than detectable levels of these pollutants.

Table 5-30 Example TMDLs and composite allocations for Cu, Hg, and Pb in upper Rock Creek at site L-23.

Metal	Flow Conditions	TMDL (lbs/day)	Percent Reduction Needed	WLA$_{(NB + MS)}$ (lbs/day)
Copper	High flow	0.030	80	0.030
	Low flow	0.0026	0	0.0026
Lead	High flow	0.012	--	0.012
	Low flow	0.0014	--	0.0014
Mercury	High flow	0.0001	--	0.0001
	Low flow	0.000006	--	0.000006

TMDLs for Rock Creek at site L-1 are presented to reflect allocations to loading below the Montana Gulch confluence.

5.7.9 Ruby Gulch (MT40E002_070)

Loading Summary

Mining sources at the Zortman Mine affect water quality in Ruby Gulch. Historic cyanide mill tailings in Ruby Gulch extended downstream for over three 3.0 miles from the mines at the head of the drainage to the confluence with Alder Gulch south of the town of Zortman. ZMI removed ore from six open pits and processed it in five leach pads located at the head of Ruby Gulch and along the divide between Ruby and Alder gulches. Deteriorating surface water quality at the Zortman mine prompted construction of the Zortman WWTP in 1994. The average annual discharge of treated water to from the plant to Ruby Gulch is 90 million gallons (170 gpm).The effluent discharges into the stream channel at site number 667 (**Figure F-1**). Flows to the treatment plant are from three capture systems in Ruby Gulch, Carter Gulch, and Alder Spur.

The Ruby Gulch capture system pumps approximately 48 million gallons per year to the treatment plant. The system consists of a collection sump and pump station, an 8.9 million gallon collection pond, a drain beneath the pond, and a pipe manifold that combines flows for routing to the treatment plant. Sources include seep discharges buried beneath the 85-86 leach pad, historic adit discharges covered b y the O.K Waste Rock Dump, and a combination of surface runoff and subsurface seepage from background the mining sources in upper Ruby Gulch. The retention pond, pump station, and manifold are in upper Ruby Gulch 1.5 miles upstream of Zortman.

The Carter Gulch capture system intercepts approximately nine million gallons of runoff and seepage from the Carter Gulch tributary that contains the Alder Gulch Waste Rock Repository (**Appendix F, Section F 2.1.1**). The valley fill waste rock structure contains a large proportion of sulfide waste. Spring rainfall in 2011, approximating the 500-year event, caused a slope failure at the base of the repository that destroyed the Carter Gulch capture system. Until it is repaired, ARD affected runoff and seepage from the repository enters Alder Gulch.

The Alder Spur capture system is located in the Alder Spur tributary of Alder Gulch. It annually intercepts seven million gallons of runoff and seepage from the leach pad and dike complex that occupies the divide between Ruby and Alder gulches.

TMDLs and Allocations

Ruby Gulch TMDLs are developed for Al, Cd, CN, Cr, Hg, and Se. The sources of metals loading to Ruby Gulch are, the Zortman WWTP, and a combination of natural background sources and mining sources not routed to the treatment plant. Therefore, the metals loading allocations for Ruby Gulch include a WLA to the Zortman WWTP (**WLA_{ZWWTP}**), a LA to natural background sources in Ruby Gulch (**$LA_{RBY\ GUL\ NB}$**), and a WLA to untreated mining sources in Ruby Gulch (**$WLA_{RBY\ GUL\ UTMS}$**). The TMDL allocations are expressed by the following equation:

$$\mathbf{TMDL = WLA_{ZWWTP} + LA_{RBY\ GUL\ NB} + WLA_{RBY\ GUL\ UTMS}}$$

This allocation scheme applies to Cd, Cr, CN and Se. The natural background concentrations of these pollutants are calculated from the dataset for the designated background sites in Alder Gulch and Ruby Gulch. Where results were less than MDLs, the sample is assumed to contain one half of the detection limit. Because of the high MDLs for Al and Hg analysis, one half of the MDL exceeded the CAL criterion for Al (87 µg/L) and the HH criterion for Hg (0.05 µg/L). Therefore, the Al and Hg TMDLs were allocated to a composite wasteload from natural background and untreated Ruby Gulch mining sources (**$WLA_{RBY\ GUL\ NB\ +\ RBY\ GUL\ UTMS}$**). The Al and Hg TMDLs are expressed according to the following Equation:

$$\mathbf{TMDL_{RBY\ GUL} = WLA_{ZWWTP} + WLA_{RBY\ GUL\ NB\ +\ RBY\ GUL\ UTMS}}$$

Table 5-31 contains example metals and cyanide TMDLs and allocations for site Z-15 in Ruby Gulch. A median high flow value of 0.4 cfs was calculated from the available flow records for site Z-15. The mean annual discharge from the Zortman WWTP is estimated at 170 gpm or about 0.38 cfs. Thus, the treatment plant discharge is about 94 percent of the flow in Ruby Gulch at site Z-15. The remaining 6 percent comes from other Ruby Gulch runoff and seepage sources. The treatment plant discharge is assumed to equal 0.38 cfs, and the remaining 0.02 cfs is equally divided between natural background and untreated mining sources. The allocations for Cd, CN, Cr, and Se TMDLs in **Table 5-31** reflect this partitioning of flow at Z-15. The allocations for Al and Hg TMDLs reflect the composite scheme for natural background and mining sources not routed to the Zortman WWTP.

Table 5-31. Metals and cyanide TMDL and allocation examples for Ruby Gulch at L-15

Metal	Flow Conditions	TMDL (lbs/day)	Percent Reduction Needed	WLA_{ZWWTP} (lbs/day)	LA_{NB} (lbs/day)	WLA_{UTMS} (lbs/day)
Aluminum	High flow	0.19	55	0.179	0.011	
	Low flow	0.056	99	0.053	0.003	
Cadmium	High flow	0.0016	94	0.0015	0.0000015	0.000095
	Low flow	0.00047	96	0.00046	0.0000021	0.000008
Cyanide	High flow	0.0112	85	0.0105	0.00016	0.00054
	Low flow	0.0034	45	0.0032	0.000049	0.00015
Chromium	High flow	0.564	--	0.53	0.000045	.034
	Low flow	0.171	--	0.161	0.0000146	0.01
Mercury	High flow	0.0001	92	0.00009	0.00001	
	Low flow	0.00003	--	0.000028	0.000002	
Selenium	High flow	0.011	50	0.0103	0.000032	0.00067
	Low flow	0.003	50	0.0028	0.0000092	0.0002

The reduction column is blank for Cr because data on which to base a reduction are not available. Only a high flow reduction is needed for Hg in Ruby Gulch. These allocation schemes assume that natural loading rates do not cause water quality standards to be exceeded and applying BMPs to mining sources will result in the loading reductions needed to meet the TMDLs and water quality standards.

5.7.10 Ruby Creek (MT40E002_060)

Loading Summary

Ruby Creek is an intermittent stream that begins at the confluence of Alder and Ruby gulches. Flow in Ruby Creek results from large precipitation or snowmelt events. Metals loading to Ruby Creek is from upstream sources in Alder Gulch and Ruby Gulch described in **Appendix F**, **F 2.1.1 and F 2.9.1**. The stream receives drainage from all but the extreme northern portion of the Zortman Mine. A portion of the 410-acre Goslin Flats land application area (LAD) is located on bench land to the west of Ruby Creek. Wastewater from the biological treatment plant at the Landusky Mine is currently sprinkler applied to 204 acres of the Goslin Flats LAD. The application rate maintained below that which would cause runoff (Spectrum Engineering, Inc., 2006). Ruby Creek is not known to flow in response to applications of wastewater to the Goslin Flats LAD.

TMDLs and Allocations

Ruby Creek is downstream of the watershed area disturbed by the Zortman Mine. Therefore, Ruby Creek metals loading from mining sources is from upstream sources in Alder and Ruby gulches. Alder and Ruby gulches are also sources of natural background metals loading. Therefore, allocations to allowable metals loading to Ruby Creek are to the following sources:

1. Natural background sources in Alder Gulch, Ruby Gulch, and Ruby Creek
2. Mining sources in Alder Gulch
3. Untreated mining sources in Ruby Gulch
4. The Zortman WWTP.

The TMDL equation reflecting allocations to the above sources is given below for the metals Cd, Pb, Se, and Zn. **Table 5-32** contains example metals TMDLs and allocations for site Z-32 in Ruby Creek.

$$\mathbf{TMDL_{RBY\ CR} = LA_{RBY\ CR\ NB} + WLA_{ALDR\ GUL\ MS} + WLA_{RBY\ GUL\ UTMS} + WLA_{ZWWTP}}$$

Natural background concentrations in Ruby Creek are assumed equal to those in Alder and Ruby gulches. Natural background concentrations of Cd, Pb, Se, and Zn are calculated from the analytical results from the monitoring sites representing natural background conditions. These sites are located in headwater tributaries of Alder Gulch (sites Z-60, Z-61, Z-62, and AGSS-10) and in Ruby Gulch tributaries draining the undisturbed eastern extent of the Ruby Gulch watershed (sites Z-52, Z-9, AGSS-1, and RGSP-1).

The loading in **Table 5-32** is based on median high and low flow rates calculated from the flow record available for site Z-32. The high flow value is 0.37 cfs; the median low flow is 0.03 cfs. The watershed area upstream of site Z-32 is larger than that upstream of site Z-15 in Ruby Gulch. Therefore, the percentage of Z-32 flow that discharges from the Zortman WWTP is much smaller than the 94 percent that the treatment plant contributes to site Z-15. The drainage area contributing flow to site Z-15 is approximately 130 acres. Most of the flow from the watershed above site Z-15 is intercepted by the Ruby Gulch capture system and pumped to the Zortman WWTP. This volume, plus that from the Carter Gulch and Alder Spur capture systems, makes the treatment plant discharge large relative to flow at Z-15. The area of the Ruby Creek watershed above site Z-32, that is not pumped to the Zortman WWTP from the three capture systems, is approximately 3,700 acres. Extrapolating the per acre water yield of 0.08 gpm/acre to the 3,700-acre watershed above Z-32 gives a water yield at Z-32 of 296 gpm. The discharge of the Zortman WWTP (170 gpm), plus the water yield at Z-32 (296 gpm) gives a theoretical total flow at Z-32 of 466 gpm. The fraction of this total flow attributable to the Zortman WWTP is 0.365 (170/466 = 0.365). Multiplying the median high flow at Z-32 (0.37 cfs or 166 gpm) times the fraction calculated for the Zortman WWTP (0.365) gives a high flow treatment plant discharge of 61 gpm (166 X 0.365 = 61). Applying the same 0.365 fraction to the median low flow at Z-32 of 0.03 cfs (13.5 gpm), gives a low flow treatment plant flow at Z-32 of five gpm (13.5 X 0.365 = 4.9).

Table 5-32 contains example TMDLs and allocations for the metals Cd, Pb, Se, and Zn at site Z-32. These are the pollutants for which natural background concentrations can be calculated from the sites selected as representing background conditions for Ruby Creek. The respective natural background concentrations (µg/L) calculated for Cd, Pb, Se, and Zn are 0.08, 1.5, 0.5, and 15.

Table 5-32. Metals TMDLs and allocation examples for Ruby Creek at Z-32

Metal	Flow Condition	TMDL (lbs/day)	Percent Reduction Needed	$LA_{RBY\ CR\ NB}$ (lbs/day)	$WLA_{ALDR\ MS}$ (lbs/day)	$WLA_{RBY\ UTMS}$ (lbs/day)	WLA_{ZWWTP} (lbs/day)
Cadmium	High	0.00151	99	0.00016	0.0004	0.0004	0.00055
	Low	0.0001	98	0.000013	0.000023	0.000023	0.000042
Lead	High	0.037	93	0.003	0.011	0.011	0.012
	Low	0.003	96	0.00024	0.0009	0.0009	0.001
Selenium	High	0.01	0	0.001	0.0027	0.0027	0.004
	Low	0.0008	80	0.00008	.000345	0.000345	0.00003
Zinc	High	0.77	96	0.03	0.23	0.23	0.28
	Low	0.0594	90	0.0024	0.018	0.018	0.021

The allocations in the table are derived by calculating natural background and WWTP contributions and subtracting the sum of these sources from the TMDL. The remaining allocation is evenly divided between the allocations to Alder Gulch mining sources and untreated mining source in Ruby Gulch. The allocation scheme in **Table 5-32** assumes that natural loading rates do not cause water quality standards to be exceeded and applying BMPs to mining sources will result in the loading reductions needed to meet the TMDLs and water quality standards.

The high MDLs reported with Al and Hg results, and the exclusive high flow sampling of the natural background sites for Cu prevent a clear allocation to natural background sources of these metals. Therefore, a composite allocation to the sum of Ruby Creek natural background sources (**RBY CR NB**), Alder Gulch mining sources (**ALDR GUL MS**), and untreated Ruby Gulch mining sources (**RBY GUL UTMS**) is proposed for Al, Cu, and Hg. The TMDL equation reflecting allocations to the above sources is given below.

$$TMDL_{RBY\ CR} = WLA_{RBY\ CR\ NB\ +\ ALDR\ GUL\ MS\ +\ RBY\ GUL\ UTMS} + WLA_{ZWWTP}$$

Table 5-33 contains example TMDLs and allocations for Al, Cu, and Hg in Ruby Creek at site Z-32 using this composite allocation scheme. The high and low flow reductions given in the **Table 5-33** for Cu reflect those required to bring the high and low flow values measured at current condition sites into compliance with the CAL criteria. The needed reductions to Al and Hg could not be identified because high MDLs prevented determining the actual departure from the HH criterion.

Table 5-33. Aluminum, copper, and mercury TMDLs and allocation examples for Ruby Creek at Z-32

Metal	Flow Condition	TMDL (lbs/day)	Percent Reduction Needed	$WLA_{RBY\ CR\ NB\ +ALDR\ GUL\ MS\ +\ RBY\ GUL\ UTMS}$ (lbs/day)	WLA_{ZWWTP} (lbs/day)
Aluminum	High	0.174	--	0.111	0.063
	Low	0.0141	--	0.009	0.0051
Copper	High	0.061	99	0.039	0.022
	Low	0.005	98	0.0033	0.0017
Mercury	High	0.0001	--	0.00006	0.00004
	Low	0.00001	--	0.000007	0.000003

The allocation scheme in **Table 5-33** assumes that natural loading rates do not cause water quality standards to be exceeded and applying BMPs to mining sources will result in the loading reductions needed to meet the TMDLs and water quality standards.

5.7.11 Sullivan Gulch (MT40E002_110)

Loading Summary

Metals loading to Sullivan Gulch is from the L91 leach pad and supporting dike that were constructed from approximately 69 million tons of largely sulfide ore and waste rock from the Landusky pit complex. The Sullivan Gulch capture system, consisting of an interception sump, pump house, and holding pond, was constructed at the base of the L91 leach pad dike in 1997. Captured wastewater is pumped to the Landusky WWTP. Other potential sources are storm runoff from the dike and pad face and the county roadway connecting the Zortman and Landusky mines.

Water quality data are available for a capture system overflow, two sites just below the capture system and a fourth site near the confluence with Rock Creek. Metal exceedances are more common and of higher magnitude at the upper sites than at site D-7 near the mouth. Most exceedances occur under high flow conditions.

TMDLS and Allocations

TMDLs for Cd, Fe, Pb, Se, and Zn in Sullivan Gulch are allocated to natural background (**SLVN GUL NB**) and mining sources (**SULVN GUL MS**) of these pollutants. The following equation states the Sullivan Gulch TMDL:

$$\mathbf{TMDL_{SULVN\ GUL} = LA_{SLVN\ GUL\ NB} + WLA_{SULVN\ GUL\ MS}}$$

Loading from natural background sources is calculated from median concentrations of pollutants measured at sites RCSS-5, Z-60, Z-61, Z-62, and L-40. Where concentrations are less than the detection limit, one half of the MDL is used in the calculation. **Table 5-34** contains TMDL and allocation examples for high and low flow conditions at site D-7 near the mouth of Sullivan Gulch. The allocations in **Table 5-34** to Sullivan Gulch mining sources are calculated as the difference between the TMDL and the LA to natural background sources.

Table 5-34. Metals TMDLs and allocation examples for Sullivan Gulch at D-7

Metal	Flow Condition	TMDL (lbs/day)	Percent Reduction Needed	$LA_{SULVN\ GUL\ NB}$ (lbs/day)	$WLA_{SULVN\ GUL\ MS}$ (lbs/day)
Cadmium	High	0.0002	94	0.000045	0.00016
	Low	0.00002	50	0.0000038	0.0000162
Iron	High	0.45	1	0.17	0.28
	Low	0.038	48	0.014	0.024
Lead	High	0.003	85	0.00224	0.00076
	Low	0.0004	90	0.00019	0.00021
Selenium	High	0.002	55	0.0002	0.0018
	Low	0.0002	0	0.000019	0.000181
Zinc	High	0.093	73	0.0045	0.0885
	Low	0.01	5	0.00038	0.00962

The allocation scheme in **Table 5-34** assumes that natural loading rates do not exceed water quality standards and that further application of BMPs to mining sources will result in the loading reductions needed to meet the TMDLs and water quality standards.

5.7.12 Swift Gulch Creek (MT40I002_010)

Loading Summary

Swift Gulch Creek is a southern tributary to South Big Horn Creek. Approximately 540 acres of the reclaimed surface of the Landusky Mine drain north to Swift Gulch Creek. The main source of metals loading to Swift Gulch Creek from the mine is ARD from beneath the August-Little Ben-Surprise-Queen Rose pit complex at the Landusky mine. The pit complex is approximately parallel to subsurface bedrock shear zones where local mineralization has increased concentrations of sulfides, particularly pyrite (FeS_2). The shear zones control the volume and direction of local groundwater flow. The shear zone extend from beneath the pit complex, northeastward into the Swift Gulch Creek watershed. The intersection of the shears and the Swift Gulch Creek channel are expressed in a series of streambank springs. Mining within the shear zones at the Landusky Mine has lowered the local water table and exposed an increased volume of sulfide bedrock to weathering. Accelerated sulfide oxidation in the mined portion of the shear zones has acidified local groundwater that enters Swift Gulch Creek at the springs. Groundwater quality in Swift Gulch Creek has been deteriorating due to metals loading since the early 1990s, with a marked increased rate of metals loading beginning in 1998 This affect is illustrated in **Figure F-18**, a graph of the sulfate concentration in Swift Gulch Creek at site L-19. Sulfate is a product of sulfide mineral oxidation. **Figure 5-12** contains graphs of As, Cu, and Fe concentrations in Swift Gulch Creek during the past two decades.

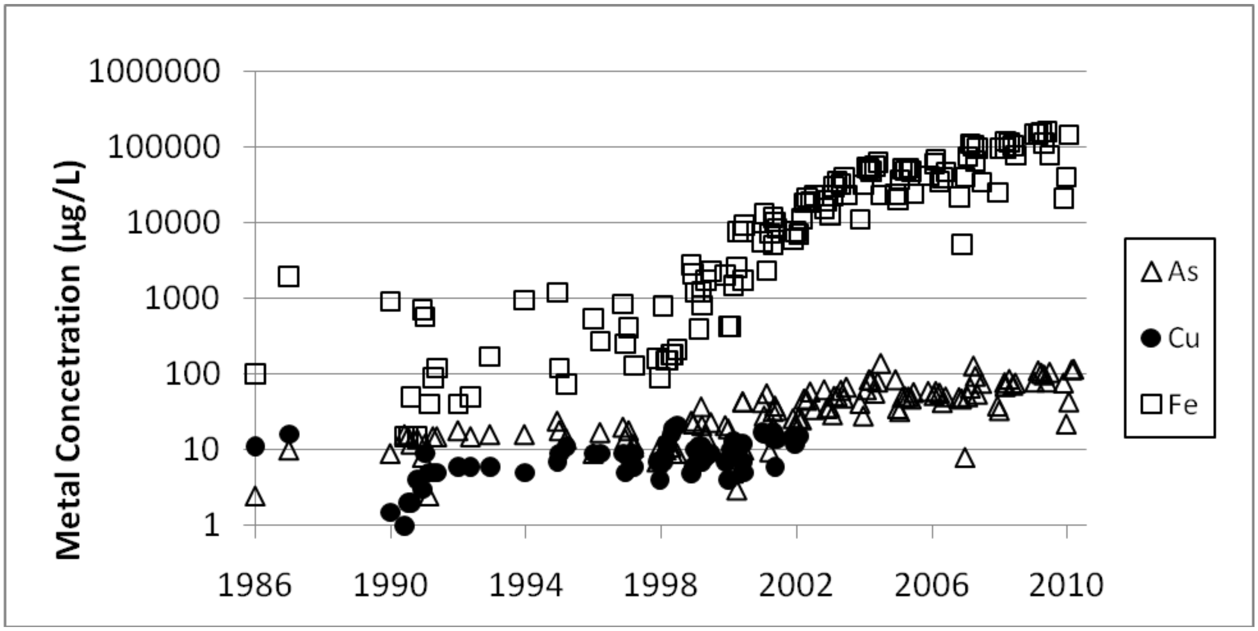

Figure 5-12. Graphs of arsenic, copper, and iron concentration at site L-19 in Swift Gulch Creek through 2010.

Although of metals targets exceedances are generally more numerous during low flows, high flow runoff sediment pulses often cause the largest individual exceedances. Large flow events usually provide dilution with higher quality precipitation of snowmelt runoff. The wide fluctuation in sulfate concentration (**Figure F-18**) illustrates the effects of clean runoff diluting higher base flow metals concentrations. Of the seven widely spaced cyanide exceedances, five occurred during high flows.

TMDLs and Allocations

Swift Gulch Creek TMDLs are allocated to natural background concentrations ($LA_{SGC\ NB}$) and mining sources ($WLA_{SGC\ MS}$) for all pollutants, except thallium. The following equation expresses the allocation scheme for Al, As, Cd, Cu, CN, Fe, Pb, Ni, and Zn:

$$\mathbf{TMDL_{SGC} = LA_{SGC\ NB} + WLA_{SGC\ MS}}$$

Table 5-35 contains TMDL and allocation examples for Swift Gulch Creek at site L-19.

Table 5-35. Metals and cyanide TMDLs and allocation examples for Swift Gulch Creek at L-19

Metal	Flow Condition	TMDL (lbs/day)	Percent Reduction Needed	$LA_{SULVN\ GUL\ NB}$ (lbs/day)	$WLA_{SULVN\ GUL\ MS}$ (lbs/day)
Aluminum	High	0.202	86	0.116	0.086
	Low	0.031	87	0.0175	0.0135
Arsenic	High	0.023	77	0.0035	0.0195
	Low	0.0035	78	0.0005	0.003
Cadmium	High	0.0013	97	0.0001	0.0012
	Low	0.0002	92	0.000018	0.000182
Copper	High	0.05	87	0.0035	0.0465
	Low	0.009	0	0.00053	0.0085

Table 5-35. Metals and cyanide TMDLs and allocation examples for Swift Gulch Creek at L-19

Metal	Flow Condition	TMDL (lbs/day)	Percent Reduction Needed	$LA_{SULVN\ GUL\ NB}$ (lbs/day)	$WLA_{SULVN\ GUL\ MS}$ (lbs/day)
Cyanide	High	0.012	0	0.0058	0.0062
	Low	0.002	94	0.0009	0.0011
Iron	High	2.32	97	0.09	2.23
	Low	0.351	99	0.014	0.337
Lead	High	0.026	96	0.003	0.023
	Low	0.0054	45	0.0005	0.0049
Nickel	High	0.279	30	0.023	0.256
	Low	0.052	73	0.0035	0.0485
Zinc	High	0.643	80	0.012	0.631
	Low	0.121	95	.002	0.119

The 3 µg/L MDL reported with thallium results exceeds the 0.24 µg/L HH criterion and precludes a separate allocation to natural background sources in SWIFT Gulch Creek. As a result, the TMDL allocation for thallium is a composite wasteload allocation that is the sum of natural background and mining sources ($WLA_{SGC\ NB\ +\ SGC\ MS}$) until additional monitoring with lower detection limits can distinguish concentration differences between these two sources. The thallium TMDL in Swift Gulch Creek is expressed in the following equation:

$$\mathbf{TMDL_{SGC} = WLA_{SGC\ NB\ +\ SGC\ MS}}$$

An example TMDL and allocation for high and low flow conditions at site L-19 in Swift Gulch Creek is contained in **Table 5-36**.

Table 5-36. Metals and cyanide TMDLs and allocation examples for Swift Gulch Creek at L-19

Metal	Flow Condition	TMDL (lbs/day)	Percent Reduction Needed	$WLA_{SGC\ NB\ +\ SGC\ MS}$
Thallium	High	0.0006	84	0.0006
	Low	0.0001	84	0.0001

The allocation schemes in **tables 5-35 and 5-36** assume that natural loading rates do not exceed water quality standards and that further application of BMPs to mining sources will result in the loading reductions needed to meet the TMDLs and water quality standards.

5.8 Seasonality and Margin of Safety

TMDLs must consider the effects of seasonal variability on water quality conditions and provide for a margin of safety to account for uncertainties in calculating contributions from pollutant sources. The margin of safety is intended to provide reasonable assurance that developed TMDLs are protective of water quality and beneficial uses. The following sections describe the considerations given to seasonality and a margin of safety for TMDLs in the Landusky planning area.

5.8.1 Seasonality

Seasonality was considered in assessing loading conditions and developing targets, TMDLs, and allocation schemes. Seasonality is important for metals due to varying metals loading pathways and varying water hardness during high flow and base flow conditions. Runoff delivery of metal contaminated sediment is the major cause of target exceedance during high flows. The amount of streamflow contributed from surface runoff also effects water hardness and the inherent toxicity of metals in surface water. Base flow exceedances are most often caused by loading from groundwater discharge from the shallow aquifer system and from perennial mining-related sources such as historic adits and seeps from extensive underground workings that predate ZMI surface mining operations. Seasonal variability in pollutant loading is address In this document in the following ways:

- Targets for hardness-dependent metal pollutants are developed based on the prevailing hardness conditions that vary with seasonal changes in streamflow contributions from runoff versus groundwater sources
- Flow data distributions were analyzed to derive characteristic high and low flows that are used in loading equations to develop corresponding high and low flow TMDLs and allocations
- Where data quality allows, needed load reductions are identified for both high and low flow conditions.

5.8.2 Margin of Safety

A margin of safety ensures that TMDLs and allocations adequately protect beneficial uses. The margin of safety is implicit in all TMDLs described above. The implicit margin of safety is applied through the following conservative assumptions applied in TMDL development:

- The Spectrum Z-L ACCESS database contains the results of monitoring that, in many cases, does not describe water quality conditions throughout the entire reach of each stream segment. A large proportion of the results are reported with method detection limits that do not allow comparison with the most restrictive aquatic life or human health criteria. The timing of past sampling may not allow an adequate evaluation of seasonal variability in water quality. Therefore, future evaluation of target attainment and load allocation adjustment is based on an adaptive management approach that relies on future to monitoring to reassess pollutant loading guide reclamation planning and implementation.
- Water quality data from instantaneous results used to quantify target departures and loading are in many cases more restrictive than data based on mean values over a 96-hour period
- Load allocations to natural background sources are based on results for samples collected from sites judged as being remote from mining disturbances. It is conceivable that water quality at these locations may continue to be influences from past mineral exploration or other human disturbances that would inflate the estimate of natural background loading and underestimate allowable loading from human-caused sources.

5.9 Uncertainty and Adaptive Management

Uncertainty is inherent in the TMDL development process. Uncertainty exists in the accuracy of chemical analysis results, flow conditions at the time of sampling, and representativeness of sampling locations and timing to current instream conditions. These uncertainties are carried forward in target values and loading assessments. The adaptive management process is an important check against perpetuating error in future assessments of loading misdirecting future remediation efforts. Therefore, the need to conduct further monitoring is imperative to an improved understanding of loading sources, impairment conditions and the processes that affect impairment. Adoption of the adaptive management approach is a realistic admission that targets, TMDLs, allocations, and the analyses supporting them are iterative processes that welcome new information.

In the atmosphere of chronic funding limitations, adaptive management provides critical feedback to help identify those restoration activities that best result in water quality improvement. It provides the flexibility to refine targets as necessary to ensure protection of the resource or to adapt to new information concerning target achievability. Additional monitoring and source refinement recommended in **Section 6.0** may be necessary determine the current extent of impairment, better describe the effects of treatment plant discharges, refine remediation strategies in area of limited seasonal access. Restoration and monitoring plans linked to the adaptive management process are and is described in **Sections 6.0** and **7.0**.

Future efforts toward water quality improvement in the Landusky TPA have a number of potential outcomes. Restoration could achieve full attainment of applicable standards. Restoration could fail to attain standards and the waterbodies remain impaired and require further restoration to reduce loading. Restoration could fail to meet standard and standards are deemed unachievable after restoration activities have been completed. In this case, site-specific water quality standards and/or the reclassification of the waterbody may be needed. This would prompt new target and TMDL development reflecting existing conditions or the best anticipated future conditions.

The TMDLs developed for the Landusky TPA are based on attainment of water quality standards and achieving support for established beneficial uses. In spite of all reasonable efforts, attainment of restoration targets may not be possible due to the potential presence of pervasive mining sources and, is in some cases natural background loading sources. The DEQ Permitting and Compliance Division, Bureau of Land Management personnel, the Fort Belknap Tribal Community, and DEQ's water quality standards program will, with the help of other stakeholders cooperate to identify appropriate remediation strategies to address mining impacts.

6.0 Framework Water Quality Restoration Strategy

6.1 Summary of Restoration Strategy

This section provides a framework restoration strategy toward water quality improvement in the Landusky planning area. The framework strategy is focused on progress in achieving the TMDLs presented in this document. This section identifies activities with potential to reduce metals and cyanide loading to listed segments. The discussion includes information on what improvements to water management systems are needed and where they would occur. This section seeks to inform stakeholders about the administrative as well as technical path to developing an adaptive Watershed Restoration Plan (WRP) in light of significant physical and financial obstacles to meeting water quality goals. A cooperatively developed WRP will provide more specifics about project priorities and spatial application of treatments for each stream.

The intent of a cooperatively developed restoration plan is to provide a locally supported list of priorities, schedule of activities, and funding opportunities for addressing problems in a headwater setting. Because of the technical obstacles and large infrastructure requirements, development of an effective restoration plan will require a unified effort among local, state, tribal, and federal entities. The watershed restoration process will initially proceed with a thorough technical evaluation of restoration alternatives and an analysis that identifies water quality improvement options that deliver the most benefit for each financial commitment. As restoration progresses and setbacks occur, the restoration strategy benefits from an adaptive approach that is informed by environmental monitoring and revised by stakeholders based on new information and advancements in treatment technology.

6.2 Role of DEQ, Other Agencies, and Stakeholders

Because of DEQ's established role in past restoration plan development, funding, and implementation, the agency will provide cooperative oversight for future pollutant reduction projects for both point source and nonpoint source activities. DEQ will also be providing continued technical and financial assistance for local, tribal and federal stakeholders with interests in improving water quality. The DEQ will work with participants to develop and fund restoration approaches that are locally supported, take full advantage of existing treatment infrastructure, and apply proven technical solutions to pollutant load reductions.

While recognizing the past leadership role of DEQ in development and implementation of mine reclamation at the Zortman and Landusky properties, it is important for local landowners and , watershed organizations to increase their involvement and collaboration with tribal, state, and federal agencies to progress toward meeting water TMDL targets and load reductions. In addition to DEQ, specific stakeholder agencies that will continue to promote restoration efforts include the Fort Belknap Tribal Environmental Department, the U.S. Department of Interior BLM, and the U.S. Environmental Protection Agency. Other agencies organizations capable of providing technical expertise, educational outreach, and possible funding include the Milk River Watershed Alliance, Phillips County Conservation District, Montana Department of Natural Resources and Conservation, and the Natural Resource Conservation Service.

6.3 Watershed Restoration Goals

The following are general water quality goals provided in this TMDL document:
Provide technical guidance for full recovery of aquatic life and human health related beneficial uses to all impaired streams within the Landusky TPA by reducing water- and sediment-bound metal loading. This technical guidance is provided by the TMDL components in the document which include:

- water quality targets,
- pollutant source assessments, and
- general restoration guidance which should meet the TMDL allocations.
- Assess watershed restoration activities to address significant pollutant sources.

A cooperatively developed restoration plan is more prescriptive and dynamic than the TMDL document. It can be refined as activities progress and address broader goals than those included in this document. The following elements are likely to be included in a future restoration plan for mined lands:

- A comprehensive update of the 2006 Engineering Evaluation and Cost Analysis for Water Management at the Zortman and Landusky Mines, Phillips County, Montana
- Interim replacement and repair of capture system components damaged during extreme precipitation in the planning area during May of 2011
- An assessment and implementation of new treatment options for leach pad effluent at the Landusky Mine.
- Water treatment infrastructure improvements capable of providing increased treatment capacity at the Zortman and Landusky treatment plants, the biological treatment system at the L87 and L91 leach pads, and the wastewater treatment system in Swift Gulch Creek
- Rehabilitation of water capture and interception systems feeding the Zortman and Landusky WWTPs
- Evaluation of additional source control options that reduce metal concentrations in water delivered to the Zortman, Landusky, and Swift Gulch Creek treatment plants.
- Reevaluation of the water quality monitoring program to reduce duplicative analyses, better characterize entire extents of affected streams, and update water quality information at selected sites lacking recent data

The water quality targets for each metal pollutant (and supplemental indicators) are described above for each metal pollutant and cyanide (**Section 5.4**)**.** These targets serve as the basis for long-term effectiveness monitoring for achieving beneficial use support. **Section 7** identifies a general monitoring strategy and recommendations designed to track water quality conditions and restoration successes.

6.4 Overview of Water Management Recommendations

TMDLs were completed for a variety of metals on 12 streams. Other streams in the watershed may be in need of TMDLs, but insufficient information about them precludes TMDL formation at this time. In general, metal loading can be reduced by focusing restoration efforts on repair and rehabilitation of existing water treatment infrastructure and by focused evaluation of additional source control options. Stream channel restoration may provide additional metals source controls in areas severely scoured by recent flooding. Other restoration options for suppressing sediment metals loading include roadway inspection and follow-up drainage control improvements, decommissioning and reclamation of abandoned mine access and exploration roads, and surface stabilization of erodible abandoned mine tailings and waste rock deposits.

6.4.1 Water Treatment System Repairs

The paragraphs below summarize damage to water treatment infrastructure resulting from high precipitation during May of 2011. Damage descriptions and repair cost estimates are from Spectrum Engineering (2011).

Carter Gulch Capture System

The Carter Gulch capture system was located at the base of the Alder Gulch Waste Rock Repository located in the eastern headwater branch of Carter Gulch (**Appendix A**, **Figure A-16**). The capture trench had a 50,000 gallon capacity and the pumping rate from the capture system to the Zortman WWTP averaged 20 gmp.

High rainfall during May of 2011 caused a slope failure at the base of the waste rock repository that destroyed the entire capture system. Remnants of the capture system and channel erosion damage were observed for 1,600 feet downstream in Carter Gulch and extending into Alder Gulch. The damage will require the complete rebuilding of the system at a cost of approximately $500,000. Options for stabilizing the waste rock repository are being reviewed. Cost range from $300,000 for buttressing of the waste rock base, $14,500,000 for complete removal of the repository.

Ruby Capture System

High precipitation caused a landslide into the Ruby Gulch pond. The sediment influx damaged the pump system delivering wastewater to the Zortman WWTP and caused a loss of pond storage volume. Bypass flows resulting from the damage are estimated at 21 million gallons. The cost of pump repair and sediment removal from the pond is estimated at $30,000.

Zortman Z85/86 Leach Pad

Infiltration into the Z85/86 pad is usually pumped at about 150 gpm into the Z89 pad for pH adjustment prior to discharge onto the Goslin Flats LAD area. Increased precipitation caused the pad storage capacity to be exceeded, requiring construction of a larger diameter pipeline to the Z89 pad and purchase of additional sodium hydroxide for pH adjustment. The increase cost to handle the extra flow and caustic requirements was $80,500.

Swift Gulch Wastewater Treatment Plant

The Swift Gulch plant was constructed in the bottom of the Swift Gulch Creek drainage in 2011. The plant is supplied by two upstream infiltration trenches. The treatment plant capacity is from 50 to 100 gpm. High streamflows caused channel scouring to a depth of about eight feet that removed both capture systems and destroyed the access road to the treatment plant. Needed repairs include rebuilding of the capture systems, rebuilding of the access road, land armoring of the plant building against future high flows. Repair costs are estimated at $250,000.

Incidental Erosion Damage

Erosion caused by high precipitation in the spring of 2011 also damaged roadways and diversion structures at both mines. Repairs are estimated to cost $20,000.

6.4.2 Water Treatment Improvement Options

The following paragraphs describe options being considered to increase metals precipitation in treated wastewater and to improve the capacity of capture systems at both mine properties.

Lime Neutralization of Landusky Leach Pad Effluent
The high acidity of drainage through the Landusky leach pads requires pretreatment using sodium hydroxide before this waste stream can be routed to the biological treatment plant for removal of cyanide, selenium, and nitrate. An option for increasing metals removal and reducing treatment costs is to replace the hydroxide treatment with neutralization by calcium oxide addition. Lime is a less expensive neutralizing agent and is capable of settling out more metal precipitates that could potentially damage the bio-treatment system. Increased metal removal of leach pad water would allow more of this wastewater to be routed to the Goslin Flats LAD area rather than to the Landusky WWTP. This would increase the capacity of the Landusky plant to treat flows from the Sullivan and Mill Gulch capture systems. This option would also reduce maintenance costs of removing sediment from the pH adjustment pond now used to pre-treat leach pad drainage prior to biological treatment.

Capture System Improvements
Seven capture systems deliver wastewater to the Landusky and Zortman WWTPs. Six systems remain with the loss of the Carter Gulch system in May, 2011. Each system generally consists of a capture trench excavated perpendicular to the channel flow direction. The downstream side of the trench is sealed with a low permeability slurry wall, fabric barrier, or a combination of these. A perforated pipe is installed in the trench bottom and covered with coarse gravel. A submersible pump is used to remove water from the buried pipe and route it to either the Zortman or Landusky plants for treatment by lime precipitation.

As the capture system age, the permeability of the gravels at each trench bottom is reduced by infiltration of fine sediments from the surrounding fill. The lower permeability of the gravels reduces the flow capacity of each system. The reduced flow capacity causes more untreated wastewater to bypass the capture trench and enter downstream surface waters. Metal concentrations in capture system bypass flows are some of the highest in the planning area. Rehabilitation of the infiltration trenches has not occurred since they were installed in the late 1990s. This option has the potential to improve water quality below the capture trenches and increase the flow of untreated to both treatment plants.

An additional strategy is available to improve the performance upper Montana Gulch capture system. The upper Montana Gulch system is located below the base of the Montana Gulch waste rock dump. It delivers about 10 million gallon of wastewater per year to the Landusky WWTP. Because of a connection between local groundwater and flow to the capture system, the amount of water from a nearby artesian well (WS-3) that is routed to the Landusky Waste Water Treatment Plant (WWTP) affects water quality in the upper Montana Gulch capture. When flows from the artesian well are reduced (the well is partially shut in) surface water seeps form in Montana Gulch below the capture system. This water contains high aluminum concentrations that enter Montana Gulch untreated. If flows from WS-3 to the treatment plant are increased the seeps disappear. Although the quality of water from well WS-3 is affected by mining, it is less contaminated than other Landusky wastewaters. An option under consideration is to use WS-3 water to dilute other Landusky waste streams, thus, maintaining high flows from WS-3 and eliminating the aluminum laden seeps below the upper Montana Gulch capture system.

6.4.3 Source Control Evaluation
The feasibility of several source reduction options requires further evaluation before the commitment of limited funding. These include the installation of infiltration barriers in areas with large volumes of sulfide rich ore or waste rock. Such efforts would be similar to the regarding, capping, and construction

of runoff controls on the surface of the Alder Gulch Waste Rock Repository completed in 2007. Potential target areas include the area overlying the Gold Bug Pit at the Landusky Mine, selected areas of the L87/91 leach pads, or portions of the August-Little Ben-Surprise-Queen Rose pit complex.

A well drilling and pump test program was initiated along the steep upper slope between the Landusky pits and Swift Gulch Creek in 2009. The purpose of the program was to determine the volume of groundwater recharge from the bottom of the pits to the shear zone transporting contaminated groundwater to Swift Gulch Creek. Further evaluation of this metals loading source would determine the feasibility of installing a low permeability grout curtain to reduce, capture, or divert metals loading to Swift Gulch Creek.

6.5 General Mine Reclamation Approaches

Rather than restoration practices specifically considered for the Zortman and Landusky mines, this section is a brief discussion of general restoration programs and funding mechanisms applicable to the metals sources, The need for further characterization of impairment conditions and loading sources is addressed through the framework monitoring plan in **Section 7.0**. A number of state and federal regulatory programs have been developed over the years to address water quality problems stemming from historic mines and associated disturbances. Regulatory programs and approaches considered most applicable to the Landusky watershed include:

- The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA),
- The State of Montana Mine Waste Cleanup Bureau’s Abandoned Mine Lands (AML) Reclamation Program.

6.5.1 Pollution Restoration Approach

“Pollution” causes of impairment are distinguished from those resulting from the loading of specific chemical pollutants, such as cadmium, nitrate nitrogen, or sediment. Although TMDLs are not developed for pollution impairments, they are often linked to pollutants, such as channel substrate alterations caused by excess sediment. Addressing pollution sources is an important part of watershed restoration. Six streams in the Landusky TPA have impairments caused by pollution. The streams and corresponding pollution impairments are contained in **Table 6-1**.

Table 6-1. Pollution Impairments in the Landusky TPA.

Stream Name	Pollution Impairment Cause
Alder Gulch	Alteration in stream-side or littoral vegetative covers
King Creek	Alteration in stream-side or littoral vegetative covers
	Physical substrate habitat alterations
Lodge Pole Creek	Alteration in stream-side or littoral vegetative covers
Mill Gulch	Alteration in stream-side or littoral vegetative covers
Rock Creek	Alteration in stream-side or littoral vegetative covers
Sullivan Gulch	Alteration in stream-side or littoral vegetative covers
	Physical substrate habitat alterations
	Fish-Passage Barrier
	Other flow regime alterations

Habitat impairments are typically addressed during implementation of sediment, nutrient, or temperature TMDLs. Although flow alterations have the most direct link with temperature, and temperature TMDLs are the only TMDLs that explicitly discusses flow, adequate flow is also critical for transporting sediment and diluting metals inputs. Therefore, if restoration goals within the Landusky TPA are not also addressing pollution impairments, additional pollution-related BMP implementation should be considered. Habitat and flow BMPs are discussed below in **Section 9.5**.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
CERCLA (a.k.a. Superfund) is a Federal law that addresses cleanup on sites, such as historic mining areas, where there has been a hazardous substance release or threat of release. Sites are prioritized on the National Priority List (NPL) using a hazard ranking system with significant focus on human health. Under CERCLA, the potentially responsible party or parties must pay for all remediation efforts based upon the application of a strict, joint and several liability approach whereby any existing or historical land owner can be held liable for restoration costs. Where viable landowners are not available to fund cleanup, funding can be provided under Superfund authority. Federal agencies can be delegated Superfund authority, but cannot access funding from Superfund.

Cleanup actions under CERCLA must be based on professionally developed plans and can be categorized as either Removal or Remedial. Removal actions can be used to address the immediate need to stabilize or remove a threat where an emergency exists. Removal actions can also be non-time critical.

Once removal activities are completed, a site can then undergo Remedial Actions or may end up being scored low enough from a risk perspective that it no longer qualifies for remedial action. Under these conditions the site is released back to the state for a "no further action" determination. At this point there may still be a need for additional cleanup since there may still be significant environmental threats or impacts, although the threats or impacts are not significant enough to justify Remedial Action under CERCLA. Any remaining threats or impacts would tend to be associated with wildlife, aquatic life, or aesthetic impacts to the environment or aesthetic impacts to drinking water supplies versus threats or impacts to human health. A site could, therefore, still be a concern from a water quality restoration perspective, even after CERCLA removal activities have been completed.

Remedial actions may or may not be associated with or subsequent to removal activities. A remedial action involves cleanup efforts whereby Applicable or Relevant and Appropriate Requirements and Standards (ARARS), which include state water quality standards, are satisfied. Once ARARS are satisfied, then a site can receive a "no further action" determination.

The use of CERCLA authority for reclamation at the Zortman and Landusky began in 2004 with a BLM Action Memorandum for Time-Critical removal actions so that reclamation and water treatment could continue in the absence of a mine operator. Federal funding for water treatment at the mines continues under CERCLA authority through the BLM.

Other Programs
In addition to the programs discussed above, other funding may be available for water quality restoration activities. These sources include the following:

Resource Indemnity Trust/Reclamation and Development Grants Program (RIT/RDGP)
EPA Section 319 Nonpoint Source Grant Program

<u>RIT/RDGP</u>

The RIT/RDG is an annual program that can provide up to $300,000 to address environmental related issues. This money can be applied to sites included on the Mine Waste Cleanup Bureau's Abandoned Mine Lands (AML) priority list, but of low enough priority where cleanup under AML is uncertain. RIT/RDG program funds can also be used for conducting site assessment/ characterization activities such as identifying specific sources of water quality impairment.

<u>Section 319 funding</u>

Section 319 grant funds are typically used to help identify, prioritize, and implement water quality protection projects with focus on TMDL development and implementation of nonpoint source projects. Individual contracts under the yearly grant typically range from $20,000 to $150,000, with a 25 percent or more match requirement. RIT/RDG and 319 projects typically need to be administered through a non-profit or local government such as a conservation district, a watershed planning group, or a county.

Program Overlap and Coordination

Within the Landusky TPA, metals-related restoration work and project oversight is occurring by state, federal and tribal government agencies. The major agencies involved are the DEQ, BLM, and Fort Belknap Tribal Community. These organizations and their principal contractor, Spectrum Engineering, Inc., contribute members to a formal working group that cooperates to review monitoring results and consult on how best to allocate funding for continued facility maintenance, repair, and reclamation at the mines. This TMDL document is focused on metals impairment and restoration in 303(d) listed streams. Future reclamation and water management will be guided by a revised Engineering Evaluation and Cost Analysis to be prepared by the BLM in the coming months.

All of the agencies are actively collaborating to promote the exchange of information and prevent duplicative efforts. The atmosphere of cooperation among the agencies allows for a fully concerted restoration effort that encourages participation by additional stakeholders.

7.0 MONITORING STRATEGY AND ADAPTIVE MANAGEMENT

7.1 INTRODUCTION

The monitoring strategies discussed in this section are an important component of watershed restoration, a requirement of TMDL development under Montana's TMDL law, and the foundation of the adaptive management approach. Water quality targets and allocations presented in this document are based on available data at the time of analysis, however the scale of the watershed coupled with constraints on time and resources often result in compromises that must be made that include estimations, extrapolation, and a level of uncertainty. The margin of safety (MOS) is put in place to reflect some of this uncertainty, but other issues only become apparent when restoration strategies are underway. Having a monitoring strategy in place allows for feedback on the effectiveness of restoration activities (whether TMDL targets are being met), if all significant sources have been identified, and whether attainment of TMDL targets is feasible. Data from long-term monitoring programs also provide technical justifications to modify restoration strategies, targets, or allocations where appropriate.

The monitoring strategy proposed in this section is a contribution toward modification of the program initiated with the Engineering Evaluation and Cost Analysis document prepared by the BLM in 2006. A more detailed monitoring effort will be guided by recommendations contained in a revision of this document currently in progress. Monitoring recommendations provided are intended to assist cooperating agencies and interested stakeholders in developing an appropriate monitoring plan to meet water quality goals. Funding for future monitoring is uncertain and may vary with economic and political changes. Prioritizing monitoring activities depends on stakeholder priorities for restoration and funding opportunities.

7.2 ADAPTIVE MANAGEMENT APPROACH

An adaptive management approach is recommended to control costs and meet the water quality standards to support all beneficial uses. This approach works in cooperation with the monitoring strategy, and as new information is collected, it allows for adjustments to restoration goals or pollutant targets, TMDLs, and/or allocations, as necessary.

7.3 FUTURE MONITORING GUIDANCE

The objectives for future monitoring in the Landusky watershed include:

- Improve the understanding of water quality conditions in stream segments with aging monitoring records in order to identify the need for additional restoration work and refine the source assessment analysis
- Gather data needed to improve the understanding of natural background and current condition loading so that TMDL development assumptions can be refined.
- Consistently gather data among agencies and other cooperators that is comparable to that needed to assess compliance with the most restrictive water quality targets
- Expand the understanding of downstream water quality beyond the boundaries where TMDLs have been developed and address issues as necessary.
- Further assess the effectiveness of reclamation efforts and adjustments to water treatment infrastructure.

7.3.1 Strengthening the Source Assessment

Identification of sources In the Landusky TPA was conducted largely through a review of the timing, location, and extent of mining and reclamation activities from 1979 to the present and review of water quality data in the Spectrum Z-L ACCESS database for corresponding water quality responses. The mining and reclamation narratives and data review are supplemented by assessment of 2009 aerial imagery and GIS information on local geology, hydrography, and location of monitoring points.

The available data and review of the current engineering evaluation and cost analysis document (Spectrum Engineering, Inc., 2006) is supplemented by personal communications with DEQ Permitting and compliance Division staff, Fort Belknap Environmental Department staff, Spectrum Engineering personnel, and limited field verification during tours of the Zortman and Landusky mines. Although the level of detail provided a basic understanding of mine operations, reclamation practices and monitoring results, the large physical extent and overlap of mine disturbances allowed only for allocation of loading from broad source categories in each stream segment. Strategies for strengthening the metals source assessment includes follow up monitoring to focus on better defining the contribution from background sources, un-mineralized versus mineralized portions of the mined area, and, in some cases, sources from abandoned mines and areas disturbed by past exploration drilling. Although the mines in the DEQ and/or MBMG databases have some information, the loading contributions from the abandoned Hawkeye (Alder Gulch) and Beaver (Beaver Creek) mines need further evaluation. Further information on the loading contribution from the near-channel road in the Beaver Creek drainage would also improve the understanding of its effect on local water quality. Traffic density in Beaver Creek may have changed since the last observations in 2005. The contribution from past, and perhaps ongoing, placer-mining in Alder Gulch and the South Big Horn Creek drainages is not well defined and some degree of field verification would be helpful in improving the source assessment for mercury in these locations. As additional information becomes available regarding contributions from these features, TMDLs may be modified via adaptive management to split composite WLAs into separate LAs and WLAs.

7.3.2 Increase and Update Available Data

While the Landusky watershed has been the recipient of significant remediation and restoration activities, recent data is still often limited depending on the stream and pollutant of interest. The TMDL development process has identified the need for regularly scheduled sampling for metal parameters, under a variety of flow conditions, at the current conditions sites listed in **Table 5-2**. The most recent data in Alder Gulch, Beaver Creek, Lodge Pole Creek, and lower Ruby Gulch is commonly from 1998. Regular water chemistry and flow data collection at source-bracketing locations, over the full extent of stream length, is needed for these streams. A revised monitoring plan should strongly consider updating these water quality and flow records.

Monitoring should also include a focused effort to quantify natural background metals loading at high and low flows. Much of the existing background data in and around the Zortman and Landusky mines covers a limited time period (1994-1998) and includes too few sampling events for an accurate description of loading during runoff and base flow periods.

7.3.3 Consistent Data Collection and Methodologies

Data record for the Landusky TPA has been collected over several decades during which analysis methods and detection limits have significantly changed. The Montana DEQ is the lead agency for developing and conducting impairment status monitoring of surface waters. The DEQ process of stream assessment and monitoring could produce a more accurate evaluation of impairment conditions if all entities collecting water quality and stream condition data employed the same sample collection and handling protocols, analytical methods, and method detection limits. Monitoring and assessment costs could be reduced if data collected by other programs within DEQ and other agencies and organizations from the same page of data collection protocols. These monitoring recommendations are based on experience with TMDL related efforts to meet water quality targets and protect beneficial uses. The efficiency of water monitoring efforts by DEQ and other natural resource programs could improve if data from all entities would allow for comparison to TMDL program goals, as well as fulfill the water quality protection responsibilities of other programs.

7.3.4 Specific Recommendations for Metals Monitoring

Monitoring to assess water quality standards compliance for trace metals needs to include analysis for a parameter suite that, for the Landusky TPA, includes Al, As, Cd, Cu, Fe, Pb, Se, and Zn). Several companion parameters are also important for identifying conditions related to metals toxicity and oxidation of sulfide minerals. These include water hardness, pH, and sulfate concentration. A second, shorter parameter list should be considered depending on the local geology and mining method. This list includes cyanide, Cr, Hg, Ni, and Tl. Total recoverable concentrations are needed for standards comparisons except for Al, where the standard is for dissolved concentrations. A regular subset of dissolve metal concentrations for all parameters is helpful for distinguishing between runoff sources and contributions from groundwater, where dissolved concentrations predominate.

Based on the data evaluations in this document, metals included in **Table 7-1** are identified as priorities for future metals monitoring in the Landusky TPA. Many of the recommendation are made to update older datasets, incorporate current MDLs, and confirm impairments for Hg and CN that are based on older data, small datasets, and high MDLs.

Table 7-1. Metals Monitoring Recommendations for Landusky TPA by stream segment.

Waterbody Segment ID	Waterbody Segment Name	Recommended Monitoring	Rationale
MT40E002_050	Alder Gulch	Cd, Cu, Hg, Pb, Se, Zn All flows	Update from 1998 Confirm existing impairments Document NB conditions
MT40M001_011	Beaver Creek	Cd, Fe, Pb All flows	Update from 1998 Confirm Cd & Fe delistings Confirm Pb impairment Document NB conditions
MT40I001_030	South Big Horn Creek,	Al All flows Lower Al MDL	Confirm Al impairment
MT40I001_040	King Creek	As, Cd All flows	Confirm new As & Cd listings
MT40I001_050	Lodge Pole Creek	Cd & Hg All flows Low level Hg method	Update from 1998; Confirm Cd &Hg listings; Establish western headwater trib. Conditions
MT40E002_100	Mill Gulch	Cu, Hg, Pb, Se All flows Low level Hg method Update L-7 conditions	Confirm Cu, Hg, Se listings; Confirm Pb delisting

Table 7-1. Metals Monitoring Recommendations for Landusky TPA by stream segment.

Waterbody Segment ID	Waterbody Segment Name	Recommended Monitoring	Rationale
MT40E002_010	Montana Gulch	As, Cd, CN, Ni, Se, Zn All flows	Confirm CN & Ni impairments; Update since 2007
MT40E002_090	Rock Creek	Cd, Cu, Hg, Pb, Se, Zn All flows Include site below MT Gulch	Update since 1998 Confirm Hg impairment
MT40E002_060	Ruby Creek	Al, Cd, Cu, Hg, Pb, Se, Zn Lower Al, Cd MDLs Low level Hg Low flows	Confirm all impairments; Update from 1998; Establish low flow conditions for entire segment
MT40E002_070	Ruby Gulch	Al, Cd, CN, Cr, Hg, Se Lower MDLs All flows Include sites Z-100 & Z-1B	Confirm all impairments; Document conditions synoptically below Zortman WWTP discharge
MT40E002_110	Sullivan Gulch	Cd, Fe, Pb, Se, Zn All flows	Confirm all pollutant listings
MT40I002_010	Swift Gulch Creek	Al, As, Cd, Cu, CN, Fe, Pb, Ni, Tl, Zn Low Al & Cd MDLs Low flows Document conditions above seep discharges Document WWTP discharge effect at low flow	Determine background and low flow conditions; Confirm CN and Tl impairments

Sediment chemistry data is lacking for the planning area. Future monitoring should include an effort to build a sediment chemistry database over a number of years to avoid high initial costs. Analytical detection limits for water column pollutant concentrations should allow assessment of use support based on the most restrictive criteria, especially for Cd and Hg.

7.3.5 Effectiveness Monitoring for Reclamation Activities

As restoration activities are implemented, watershed-scale monitoring may be valuable in determining if restoration activities are improving water quality, instream flow, and aquatic habitat and communities. It is important to remember that degradation of aquatic resources happens over many decades and that restoration is also a long-term process. An efficiently executed long-term monitoring effort is an essential component to any restoration effort.

Due to the natural high variability in water quality conditions, trends in water quality are difficult to define and even more difficult to relate directly to restoration or other changes in management. Improvements in water quality or aquatic habitat from restoration activities will most likely be evident in fine sediment deposition and channel substrate embeddedness, changes in channel cumulative width/depths, improvements in bank stability and riparian habitat, and changes in communities and distribution of bio-indicator species. Specific monitoring methods, priorities, and locations will depend heavily on the type of restoration projects implemented, landscape or other natural setting, the land use influences specific to potential monitoring sites, and budget and time constraints.

As restoration activities continue throughout the watershed, pre and post monitoring so as to understand the changes that follow will be necessary to track the effectiveness of specific given practices or implementation projects. The following section describes recommendations applied to mined lands.

7.3.6 Reclamation in Areas Affected by Mining

Each reclamation site will have site-specific needs but general recommendations for mine site remediation effectiveness monitoring are outlined in **Table 7-2**.

Table 7-2. Effectiveness monitoring recommendations for mine site reclamation.

Parameter	Monitoring Recommendations
Water quality	Sample for heavy metals, pH, flow and TSS in water column at high and low flow above and below specific sources. Collect sediment samples at low flow. Monitoring should occur prior to remediation efforts and continue for at least 10 years after site restoration. If possible, monitoring should include biomonitoring (i.e. periphyton and macroinvertebrates) at low flow every 3 years.
Vegetation re-establishment	Greenline survey every 3 years, including bank stability, shrub regeneration, and bare ground. Vegetation transects across floodplain for vegetation community structure and regeneration.

7.3.7 Watershed Wide Analyses

The BMPs listed above are only a sample of the potential management practices that could be used in the Landusky TPA to improve water quality and habitat. Recommendations for monitoring in the planning area should not be confined to only those streams addressed within this document. The water quality targets presented here are applicable to most streams draining the Little Rocky Mountains, and the absence of a stream from the State's 303(d) List does not necessarily imply full support for all beneficial uses. Furthermore, as conditions change over time and land management evolves, the consistent application of data collection methods and information collected throughout the planning area will best allow resource professionals to identify problems as they occur, and to track improvements over time. The recommendations and TMDLs developed in this document also relate to, and will ultimately help achieve the eventual TMDLs to be developed for downstream segments that appear on the 303(d) List for metals.

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